Biological Assessment Report

Woods Fork (WBID 2429), Christian County, Missouri

Fall 2016 – Spring 2017

Prepared for:
Missouri Department of Natural Resources
Division of Environmental Quality
Water Protection Program
Water Pollution Control Branch

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TABLE OF CONTENTS

Section			Page
1.0	Introduction		1
	1.1	Justification	1
	1.2	Objectives	2
	1.3	Null Hypotheses	2
2.0	Methods		2
	2.1	Study Timing	2
	2.2	Study Area, Station Locations and Descriptions	2
		2.2.1 Ecological Drainage Units	3
		2.2.2 Land Use Description	6
	2.3	Stream Habitat Assessment Project Procedure	6
	2.4	Biological Assessment	7
		2.4.1 Macroinvertebrate Sampling, Identification, and Analyses: Primary Metrics	7
		2.4.2 Macroinvertebrate Analyses: Secondary Metrics	8
		2.4.3 General Water Quality Sampling and Analyses	8
		2.4.4 Discharge	9
	2.5	Quality Control	9
3.0	Results		9
	3.1	Stream Habitat Assessment	10
	3.2	Biological Assessment	11
		3.2.1 Macroinvertebrate Community Analyses: Primary Metrics	11
		3.2.2 Macroinvertebrate Community Analyses: Secondary Metrics	15
		3.2.2.1 Percent Sensitive Taxa Distribution	15
		3.2.2.2 Dominant Macroinvertebrate Taxa	17
		3.2.3 General Water Quality Analyses	19
		3.2.4 Total Metals in Surface Water	21
4.0	Discussion		21
	4.1	Stream Habitat Assessment	22
	4.2	Biological Assessment	25
		4.2.1 Macroinvertebrate Community Analyses: Primary Metrics	25
		4.2.2 Macroinvertebrate Community Analyses: Secondary Metrics	26
		4.2.3 Physicochemical Water Quality	30
5.0	Summary		33
6.0	Conclusions		33
7.0	Recommendations		34
8.0	Literature Cited		34

TABLES

Page

Table 1 Locations and Descriptions of Woods Fork and Bull Creek Stations 2016-2017 3
Table 2 Percent Land Use/Cover for Woods Fork, Christian County Stations (HUC-12) and the Ozark/White EDU....6
Table 3 Stream Habitat Assessment Project Procedure (SHAPP) Scores For Comparison with SHAPP Control Stream 11
Table 4 Woods Fork Stations, Fall 2016 – Individual Metric Values and Scores, Macroinvertebrate Stream Condition Index Scores (MSCI) and Biological Support Category by Station; Biological Criteria Scoring Table (bottom in gray) Used to Calculate Metric Scores 12
Table 5 Woods Fork Stations, Spring 2017 – Individual Metric Values and Scores, Macroinvertebrate Stream Condition Index Scores (MSCI) and Biological Support Category by Station; Biological Criteria Scoring Table (bottom in gray) Used to Calculate Metric Scores 14
Table 6 Percent Sensitive Taxa Distribution in Woods Fork Stations and BIOREF Streams of the Ozark/White EDU, Fall 2016 15
Table 7 Percent Sensitive Taxa Distribution in Woods Fork Stations and BIOREF Streams of the Ozark/White EDU, Spring 2017....16
Table 8 Dominant Macroinvertebrate Taxa Percentage (and Rank) for BIOREF and Woods Fork Stations, Fall 2016....18
Table 9 Dominant Macroinvertebrate Taxa Percentage (and Rank) for BIOREF and Woods Fork Stations, Spring 2017 19
Table 10 Fall 2016 Woods Fork Physicochemical Water Constituents 20
Table 11 Spring 2017 Woods Fork Physicochemical Water Constituents ...21

FIGURES

Page

Figure 1 Woods Fork in the Ozark/White EDU, 2016-2017 4
Figure 2 Woods Fork Stations, Christian County, Fall 2016 and Spring 2017....5
Figure 3 TR and EPTT per Station, Fall 2016 13
Figure 4 TR and EPTT per Station, Spring 2017....14
Figure 5 Percent Sensitive Taxa per Station, Fall 2016 16
Figure 6 Percent Sensitive Taxa per Station, Spring 2017....17

ATTACHMENTS

Appendix A	Macroinvertebrate Bench Sheet Report: Woods Fork, Christian County, Fall 2016 and Spring 2017. Grouped by Season and Station, Upstream to Downstream.
Appendix B	Photographs of Woods Fork Stations
Appendix C	Images of Woods Fork Upstream and Downstream US65
Appendix D	Images of Bull Creek from Woods Fork Confluence to Tri County Sand and Gravel Mine and Unnamed Gravel Mine near Walnut Shade, MO (Upstream to Downstream)

1.0 Introduction

Woods Fork (WBID 2429) is a small stream (Strahler stream order 1-4) located in the Ozark/White Ecological Drainage Unit (**EDU**) in southwest Missouri, approximately 10 miles south of Springfield, Missouri (Figure 1). Woods Fork (**WF**) flows southeast from Highlandville, Missouri, for approximately 15 miles in Christian County before reaching its confluence with Bull Creek near Saddlebrooke, Missouri (Figure 2). Woods Fork flows through the Missouri Department of Conservation's Busiek State Forest and Wildlife Area (**SF**). The WF watershed encompasses approximately 41 square miles.

The upstream portion of WF is unclassified (Figure 2, in blue), but it has a class C designation in most of the study area (MoDNR 2014). A class C stream is defined as an intermittent stream that may cease flow during dry periods, but maintains permanent pools that support aquatic life (MoDNR 2014). The stream has assigned beneficial use designations that include livestock and wildlife watering (**LWW**), protection of aquatic life (**AQL**), and whole-body contact (**WBC**) – category B (MoDNR 2014). Category B applies to waters designated for whole body contact recreation not contained within Category A. Whole body contact Category A is defined as:

> *…waters that have been established by the property owner as public swimming areas welcoming access by the public for swimming purposes and waters with documented existing whole body contact recreational use(s) by the public. Examples of this category include, but are not limited to: public swimming beaches and property where whole body contact recreational activity is open to and accessible by the public through law or written permission of the landowner* (MoDNR 2014).

1.1 Justification

Woods Fork was chosen by the Missouri Department of Conservation (**MDC**) as one of 25 Conservation Opportunity Areas (**COA**s) in MDC's Southwest Region (Nigh 2005, Culler 2010). A COA is selected to represent areas of high aquatic biodiversity, relatively low areas of human environmental stress, and a high proportion of public land ownership. Much of the COA is managed by MDC Busiek State Forest and Wildlife Area (Figure 2). The area was selected as an aquatic COA because five species of concern were predicted to occur in WF (Nigh 2005). In a subsequent study, MDC found that fish communities were highly impaired in WF stream orders 1-4 (Culler 2010). Stations WF #3 and WF #2 in this study (Figure 2) are located on the MDC Busiek SF and are near stations used by MDC in Culler's 2010 study.

Woods Fork is on the 2016 EPA Approved 303(d) Listed Waters (MoDNR 2016a). A 5.5 mile long stream segment was listed as impaired in 2014. The pollutant is listed as "Fishes Bioassessment/Unknown" with a Medium priority. The listing was based on fish community data collected by MDC as part of their Resource Assessment and Monitoring (**RAM**) Program (MoDNR 2015b). This current biological assessment study was conducted as a result of earlier MDC studies.

This biological assessment study was conducted in the fall of 2016 and spring of 2017 at the request of the Missouri Department of Natural Resources (**MoDNR**), Water Protection Program (**WPP**) – Water Pollution Control Branch (**WPCB**). The project was conducted by the Division

of Environmental Quality (**DEQ**), Environmental Services Program (**ESP**), Water Quality Monitoring Section (**WQMS**), and Chemical Analysis Section (**CAS**).

1.2 Objectives

- Assess the stream habitat quality.
- Assess the "protection of aquatic life" designated beneficial use status using attributes of the benthic macroinvertebrate community.
- Assess physicochemical water quality.

1.3 Null Hypotheses

1) Stream habitat quality at Woods Fork will be comparable to the stream habitat controls.

2) Macroinvertebrate Stream Condition Index (**MSCI**) scores will indicate that Woods Fork is fully supporting of the AQL beneficial use, and individual biological metric values will be within the optimum scoring range of wadeable/perennial reference stream biological criteria during the 2016 and 2017 seasons.

3) Secondary metrics (Percent Sensitive Taxa and Dominant Macroinvertebrate Taxa composition) will indicate that Woods Fork macroinvertebrate communities are similar to biological criteria reference streams (**BIOREF**) and among stations.

4) Physicochemical water quality constituents will be within acceptable limits as specified in Missouri's Water Quality Standards (**WQS**; MoDNR 2014) and will not be notable when compared to other suggested guidelines (EPA 2000), as well as among stations.

2.0 Methods

Kenneth B. Lister, Carl Wakefield, Rachel Heth, and other ESP personnel were involved in aspects of this study. Methods and study timing are outlined in this section. The study area, station locations and descriptions, EDUs, and land uses are described below. Sample collection and analysis procedures for the stream habitat assessment and the biological assessment are outlined in this section.

2.1 Study Timing

Biological assessment samples were collected in the fall of 2016 and spring of 2017. Stream habitat assessments were conducted and fall biological assessment samples were collected on October 3-4, 2016, and spring samples were collected on April 12-13, 2017. Bull Creek #10.1 (stream habitat assessment control) was assessed on August 16, 2016.

2.2 Study Area, Station Locations and Descriptions

The study area is located within the Ozark/White Ecological Drainage Unit (Figure 1). Four stations were sampled for assessment of WF (Table 1; Figure 2). Stations are identified numerically from high (upstream) to low (downstream). The Quality Assurance Project Plan (**QAPP**) called for two stations to be positioned upstream of U.S. Highway 65 (**US65**) and two

stations downstream from US65 (MoDNR 2017). Woods Fork upstream of US65 is considered a losing stream (MoDNR 2014) and was dry during every visit, so it was necessary for all stations to be downstream from US65.

Woods Fork #4 was the farthest upstream and although unclassified, it appeared to have perennial flow approximately 1.0 mile downstream from US65. Woods Fork #3 is near the northern boundary of MDC's Busiek SF. Woods Fork #2 is also in Busiek SF, approximately 0.5 miles downstream from Camp Creek. Woods Fork #1 is located just upstream of the Bull Creek confluence. The entire study reach was approximately 15 miles long. The length of each station was approximately 20-times the average width of the stream reach, which is consistent with the *Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure* (**SMSBPP**; MoDNR 2012).

2.2.1 Ecological Drainage Units

As mentioned, WF (WBID 2429) is located in the Ozark/White Ecological Drainage Unit (**EDU**; Figure 1). An EDU is an area that is characterized by its natural terrestrial physiographic division and major riverine watershed components. Ecological Drainage Units are described in detail by Sowa et al. (2007). Streams within an EDU are expected to contain similar habitat conditions and distinct biological communities. As such, stream habitat, biological communities, and physicochemical components within an EDU should be comparable between test streams and reference streams.

Table 1
Locations and Descriptions of Woods Fork and Bull Creek Stations 2016-2017

Station (WBID)	County	Location	Description	Purpose	Class
Woods Fork #4 (3690)	Christian	NW ¼ sec. 03, T. 25 N., R. 21 W. UTME479779; UTMN4083894	US - West of Woods Fork Road	Test	U
Woods Fork #3 (2429)	Christian	NE ¼ sec. 15, T. 25 N., R. 21 W. UTME480762; UTMN4080015	US in Busiek SF	Test	C
Woods Fork #2 (2429)	Christian	NE ¼ sec. 22, T. 25 N., R. 21 W. UTME480505; UTMN4079199	DS in Busiek SF	Test	C
Woods Fork #1 (2429)	Christian	SE ¼ sec. 24, T. 25 N., R. 21 W. UTME483446; UTMN4077856	DS of Busiek SF; US Confluence Bull Creek	Test	C
Bull Creek #10.1 (2423)	Taney	SE ¼ sec.36, T. 25 N., R. 21 W. UTME483845; UTMN4074659	DS - LWB Dry Hollow Rd. apx. 100 yards	SHAPP Control	P

WBID = Water Body Identification; P=Permanent, C=Intermittent, U=Unclassified; SHAPP=Stream Habitat Assessment Project Procedure; LWB=low-water bridge; MUDD = Missouri Use Designation Dataset; US = upstream; DS = downstream; SF = State Forest.

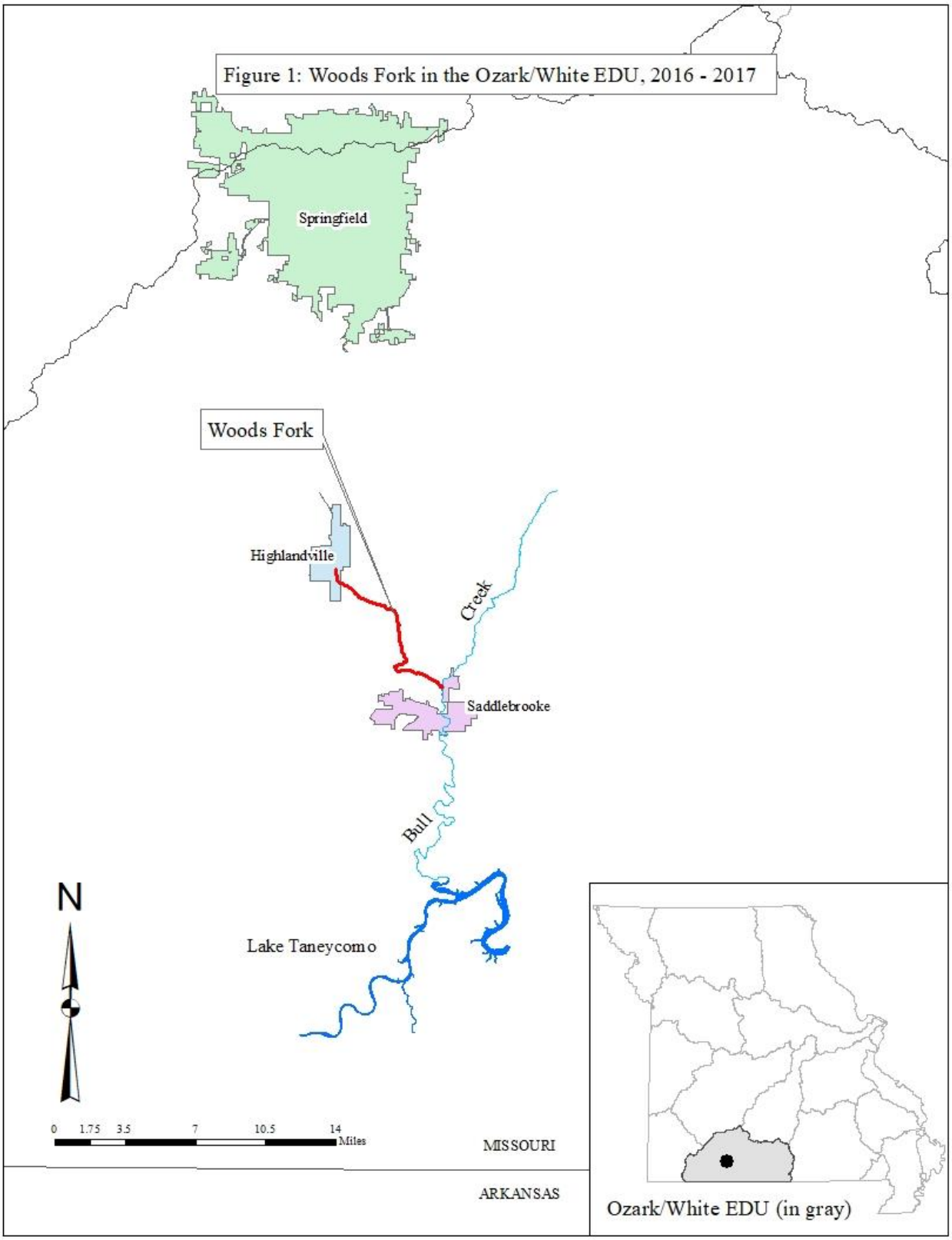


Figure 1: Woods Fork in the Ozark/White EDU, 2016 - 2017
Springfield
Woods Fork
Highlandville
Creek
Saddlebrooke
Bull
Lake Taneycomo
N
0 1.75 3.5 7 10.5 14
Miles
MISSOURI
ARKANSAS
Ozark/White EDU (in gray)

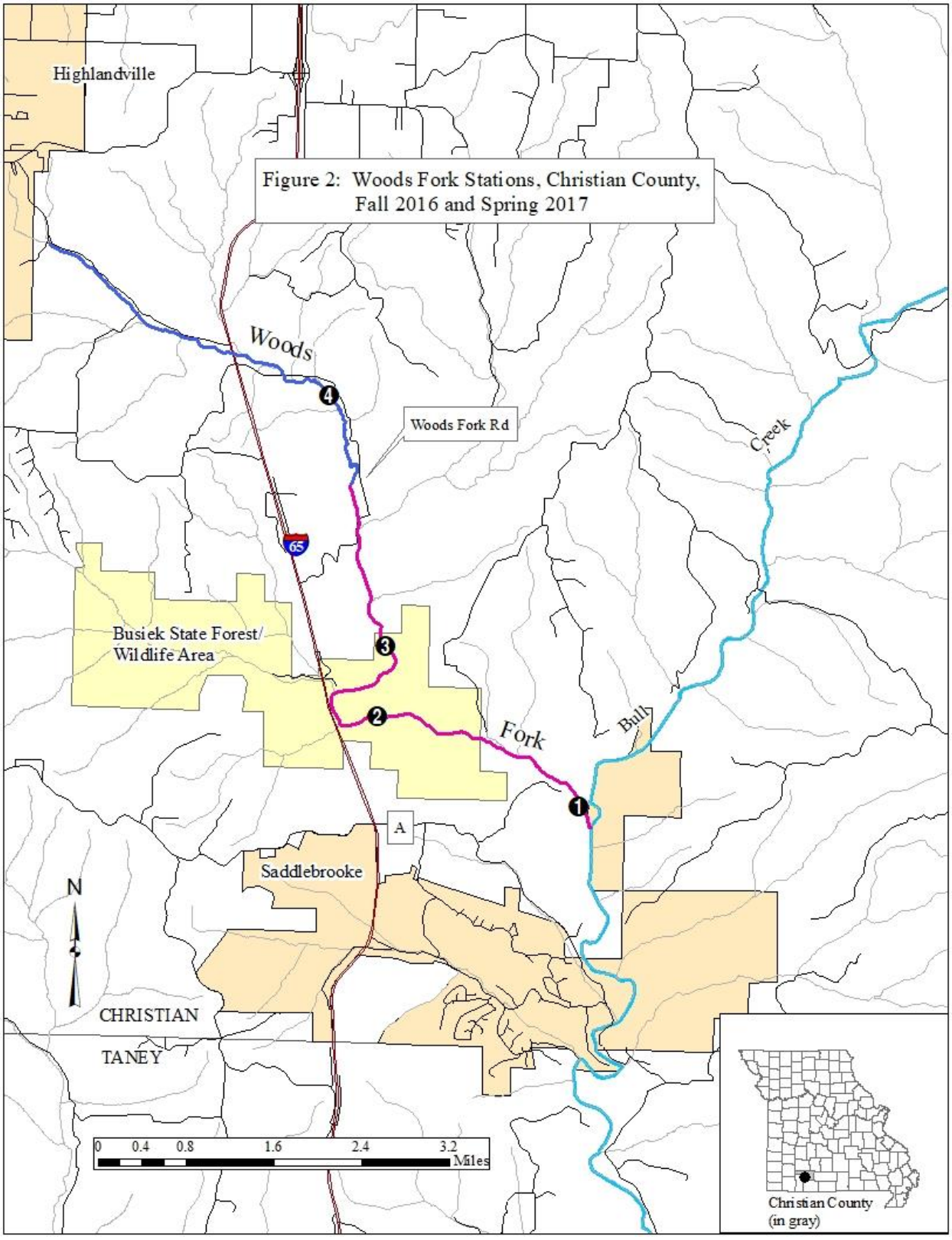


Figure 2: Woods Fork Stations, Christian County, Fall 2016 and Spring 2017
Highlandville
Woods
Fork
Creek
Woods Fork Rd
Bull
65
Busiek State Forest/
Wildlife Area
A
Saddlebrooke
N
CHRISTIAN
TANEY
0 0.4 0.8 1.6 2.4 3.2
Miles
Christian County
(in gray)

2.2.2 Land Use Description

Land use data in the WF study area and the overall Ozark/White EDU are presented in Table 2. Land uses were identified for each station's 12-digit Hydrologic Unit Code (**HUC-12**) area. The percent land use data were derived from Thematic Mapper satellite data collected between 2000 and 2004 and interpreted by the Missouri Resource Assessment Partnership (**MoRAP**). Land uses were compared by percentage among stations and with the overall EDU.

Land use within a watershed may affect the status of a station or stream. Examining potential land use contributors on a smaller scale (e.g. among stations) or a larger scale (e.g. between stations and the EDU) may aid in explaining bioassessment results. As all WF stations were in the same HUC-12 (Table 2), land uses were identical among stations at the scale used. Forest was the most abundant (63 percent) land cover followed by grassland (28 percent). This pattern was similar to the uses of the Ozark/White EDU, with forest being the most abundant (48 percent) followed by grassland (37 percent). The EDU, however, contained a lower percentage of forest cover and a higher percentage of grassland compared to the WF stations.

Table 2
Percent Land Use/Cover for Woods Fork, Christian County
Stations (HUC-12) and the Ozark/White EDU

Stations/Land-Use *HUC-12 110100030-*	WF #4 *-104*	WF #3 *-104*	WF #2 *-104*	WF #1 *-104*	Ozark/ White EDU
Impervious	1.9	1.9	1.9	1.9	1.5
Urban	0.5	0.5	0.5	0.5	2.0
Barren	1.0	1.0	1.0	1.0	1.5
Crop	0.2	0.2	0.2	0.2	1.3
Grassland	28.7	28.7	28.7	28.7	37.2
Forest	63.1	63.1	63.1	63.1	48.0
Woody/Herbaceous	4.2	4.2	4.2	4.2	5.9
Wetland	--	--	--	--	0.1
Open-water	0.3	0.3	0.3	0.3	2.5

2.3 Stream Habitat Assessment Project Procedure

The standardized *Stream Habitat Assessment Project Procedure* (**SHAPP**) was followed as described for riffle/pool prevalent streams (MoDNR 2016c). According to the SHAPP, stream habitat quality can influence the biological community composition. The habitat quality of WF test stations was compared to the habitat quality of a control stream (SHAPP control). Bull Creek #10.1, located in Christian and Taney counties, served as the SHAPP control for the Ozark/White EDU (Table 1). Habitat parameters are assigned scores, which are compiled for each test station and the SHAPP control. The SHAPP score for each WF station was expressed as a percentage of the SHAPP control. If the SHAPP score at a test station is ≥75 percent of the

control scores, the stream habitat at that test station is considered to be comparable to the habitat of the control. Additionally, individual habitat parameters or scores may be compared among stations to identify areas of interest. Notable habitat parameters are defined as those attaining scores of half or less of the possible score; they are highlighted and later compared among stations.

2.4 Biological Assessment

This biological assessment was conducted using methods described in the SMSBPP (MoDNR 2012). A biological assessment involves examination of the macroinvertebrate community metrics and the water's physicochemical quality. Primary metrics are numeric descriptions of the macroinvertebrate community composition that ultimately determine the stream's ability to support its beneficial uses. Secondary metrics are used to further examine the macroinvertebrate community composition, which may highlight similarities and differences in the test stream and BIOREF communities. Water quality constituents were compared to Missouri's Water Quality Standards (MoDNR 2014), as well as other available thresholds. Biological assessments are grouped by season and station.

2.4.1 Macroinvertebrate Sampling, Identification, and Analyses: Primary Metrics

Macroinvertebrates were sampled, identified, and analyzed from multiple habitats as described in the SMSBPP (MoDNR 2012). Woods Fork is considered a riffle/pool dominant stream. As such, coarse substrate (**CS**; riffle), non-flowing water over depositional substrate (**NF**), and rootmat (**RM**) habitats were sampled. In the WQMS laboratory, macroinvertebrates were subsampled from the benthic material in each habitat. These macroinvertebrates were then identified to specific taxonomic levels (MoDNR 2016d). Primary metrics generated from these macroinvertebrate data were used to calculate the Macroinvertebrate Stream Condition Index (**MSCI**). Ultimately, MSCI scores and the biological assessment narrative will gauge the test stream's ability to support the designated beneficial use for the protection of aquatic life.

A stream condition index using macroinvertebrates was developed as means to measure a stream's aquatic biological integrity (Rabeni et al. 1997). The index was further refined to include biological criteria that were generated using wadeable/perennial biological reference streams (**BIOREF**) for each EDU, as described in *Biological Criteria for Perennial/Wadeable Streams* (MoDNR 2002).

An MSCI score is developed by compiling rank metric scores that are calculated for individual biological metric values. The four primary biological metrics used to calculate the MSCI are 1) Taxa Richness (**TR**), 2) Ephemeroptera/Plecoptera/Trichoptera Taxa (**EPTT**), 3) Biotic Index (**BI**), and 4) Shannon Diversity Index (**SDI**). Each metric value for a test station is compared to the BIOREF criteria thresholds. The metric then receives a score of 5, 3, or 1 depending on where the metric value falls within the BIOREF scoring range. All four metric scores are then added together to calculate the MSCI for each station. MSCI scores are interpreted as follows: 20-16 = fully supporting; 14-10 = partially supporting; and 8-4 = non-supporting of the AQL beneficial use designation. MSCI scores were calculated for each station and grouped by season.

2.4.2 Macroinvertebrate Analyses: Secondary Metrics

Secondary metrics can be used to further refine examination of the community composition or support findings of the primary metrics. A "percent sensitive taxa" (**PST**) comparison between BIOREF streams (in aggregate) and individual test streams may be made if the BI metric values were outside the optimum scoring range (MoDNR 2012). A comparison may also be conducted between the "dominant macroinvertebrate taxa" (**DMT**) of BIOREF streams (in aggregate) and test stations, as well as among test stations themselves. These secondary metrics may be used to identify similarities and differences among macroinvertebrate communities (MoDNR 2012).

The PST metric is a closer examination of taxa groups that contributed to the BI metric value. Taxa are grouped based on their sensitivity to organic pollution or disturbance. The PST metric numerically describes sensitive and tolerant groups that may be compared between test stations and BIOREF samples (in aggregate), as well as among stations. The BI value range is from 0 (sensitive) to 10 (tolerant). To develop the PST, the percentage of taxa with BIs above and between the 90^{th}, 75^{th}, 50^{th}, 25^{th} and below the 25^{th} percentile are calculated based on the total number of individuals in the subsample. In this project, the "sensitive" taxa group contains taxa with BI values <5.0, and the "tolerant" taxa group contains taxa with BI values ≥7.5. "Very sensitive" is a subgroup that is made up of taxa with a BI <2.5.

The DMT metric is used to compare the 10 most abundant taxa in BIOREF streams (in aggregate) versus test stations (MoDNR 2012). It is expected that in the absence of stressors, the top 10 test station taxa should be similar to the top 10 BIOREF taxa. DMT are described as a percentage of the total number of individuals in the sample, and ranked based on their abundance at the station or stream. A test station DMT is considered to be substantially different from the reference community if the BIOREF DMT is absent or ranked outside the top 10 in a test station. Differences among stations may suggest the presence or potential sources of stressors. Results were arranged by season and station.

A complete taxa list is available in the attached *Macroinvertebrate Bench Sheet Report* (Appendix A). The bench sheet report is arranged by season and station.

2.4.3 General Water Quality Sampling and Analyses

Physicochemical water samples were collected, handled, and analyzed according to applicable Standard Operating Procedures (**SOPs**). Results for physicochemical water constituents are grouped by season and station.

Physicochemical water constituents were either recorded from field measurements or analyzed at the ESP environmental laboratory. Water was sampled according to SOP MDNR-ESP-001 *Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations* (MoDNR 2016b). Temperature (°C), pH (standard units), specific conductance (µS/cm), dissolved oxygen (mg/L), and discharge (cubic feet per second-**cfs**) were measured *in situ*. The ESP's CAS conducted analyses for ammonia as nitrogen (**NH_3-N**; mg/L),

nitrate+nitrite as nitrogen (**NO_3+NO_2-N**; mg/L), total nitrogen (**TN**; mg/L), chloride (**Cl**; mg/L), sulfate (**SO_4**; mg/L), total phosphorus (**TP**; mg/L), non-filterable residue (**NFR**; mg/L), calcium (**Ca**; mg/L), magnesium (**Mg**; mg/L), and hardness as $CaCO_3$ (mg/L). Turbidity (nephelometric turbidity unit, **NTU**) was measured and recorded in the WQMS biology laboratory. All samples collected for analysis were kept on ice during transport to ESP.

Surface water physicochemical results were compared to Missouri's Water Quality Standards (MoDNR 2014) and suggested guidelines. Because Missouri does not currently have nutrient criteria for streams and rivers, nutrient values were compared to suggested guidelines contained in *Ambient Water Quality Criteria Recommendations for Rivers and Streams in Nutrient Ecoregion XI* (EPA 2000). The EPA *Aggregate Nutrient Ecoregion XI, level III (sub) ecoregion 39* recommended reference condition values used for comparison were as follows: NO_3+NO_2-N (0.239 mg/L), turbidity (1.425 NTU), TN (0.379 mg/L), and TP (0.006625 mg/L).

Although the suggested guidelines listed above contain scientific recommendations regarding ambient concentrations of nutrients that protect aquatic resource quality, they do not substitute for Clean Water Act (**CWA**) or EPA regulations, nor are they regulations themselves. The criteria were empirically derived to represent conditions of surface waters that are minimally affected by human activities and are protective of aquatic life and recreational uses (EPA 2000).

Surface water at all stations was sampled and analyzed for total metals in the spring, according to MDNR-ESP-001. Cadmium (**Cd**), lead (**Pb**), and zinc (**Zn**) concentrations (µg/L) were analyzed for each station.

2.4.4 Discharge

Stream discharge was measured using a Marsh-McBirney Flo-Mate 2000™ flow meter at each station. Velocity and depth measurements were recorded at each station, and discharge was calculated according to SOP MDNR-ESP-113 *Flow Measurement in Open Channels* (MoDNR 2015a).

2.5 Quality Control

Quality assurance for this study is outlined in the FY 2017 *Quality Assurance Project Plan* (**QAPP**; MoDNR 2017). Quality control procedures were conducted in accordance with applicable Department SOPs and the *Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure* (MoDNR 2012). Duplicate macroinvertebrate and water chemistry samples were collected among several assigned streams, and processed as required by the FY 2017 QAPP (MoDNR 2017); no duplicates were collected at Woods Fork.

3.0 Results

Results from stream habitat assessments and biological assessments, which include macroinvertebrate and water physicochemical analyses, are presented in this section. Notable results or trends are highlighted for each section. Results are grouped by season and station.

3.1 Stream Habitat Assessment

Stream habitat quality was compared between the test stations and Bull Creek #10.1, the SHAPP control (Table 3). If a SHAPP score at a test station is ≥75 percent of the control score, the stream habitat quality in the test station is considered to be comparable to that of the control (MoDNR 2016c). Bull Creek #10.1 achieved a score of 143. Appendix C has photographs showing flow conditions of several WF stations in the fall when SHAPPs were conducted.

The stream habitat score of WF #4 (143) was identical to the control. Unlike other WF stations and the SHAPP control, WF #4 lacked deep water, which affected the Velocity Depth Regime score. Vegetative Protection (bank cover) and low Riparian Corridor values reduced the overall score. Unlike all other WF stations, flow (channel flow status) was much more apparent and covered approximately 75 percent of the available channel in the fall (Appendix B-1).

The WF #3 SHAPP score (123) was considered comparable with an 86 percent similarity to the SHAPP control. Measurements that contributed to the slightly lower score include Channel Flow Status (wetted width), Riffle Quality, Vegetative Protection, and shallow Riparian Corridor (Left Bank). Surface flow was sparse in the upstream portion of this station near the MDC property line (Appendix B-2, B-3) and was present bank-to-bank only in a narrow area for a short distance in the downstream portion of the sample reach. Bank-to-bank surface water occurred in approximately 10 percent of the overall station length.

The WF #2 SHAPP score (137) was comparable with a 96 percent similarity to the SHAPP control. The stream was very narrow so the Channel Flow Status scored low, and there was little Vegetative Protection. These two metrics contributed to the slightly lower score. The station had bank-to-bank flow for approximately 20 percent of the station length, but downstream flow was isolated in short riffles and small pools. Surface flow was abundant for a short distance (approximately 100 yards) in the upstream portion of the station but was absent downstream except for one or two scattered pools.

The WF #1 SHAPP score (123) was considered comparable with an 86 percent similarity to the SHAPP control. Although it was comparable to the control, the score was tied with WF #3 for lowest among stations. The wetted channel was very narrow and scarce, lowering the Channel Flow Status score. Riffle Quality was low due to mostly dry conditions. Vegetative Protection, and a narrow Riparian Corridor (Left Bank) were factors that also reduced the overall SHAPP score. Surface flow was very sparse, being present in short riffles and small pools scattered for a distance of approximately 150 yards.

Table 3
Stream Habitat Assessment Project Procedure (SHAPP) Scores (20 points for each variable, except where labeled) for Comparison with SHAPP Control Stream (Bull Creek #10.1)

Habitat Assessment Variable	WF #4	WF #3	WF #2	WF #1	SHAPP Control
Epifaunal Substrate	19	18	17	19	17
Embeddedness	18	19	16	17	16
Velocity/Depth Regime	**10**	15	14	13	16
Sediment Deposition	19	15	15	15	13
Channel Flow Status	11	**3**	**5**	**2**	10
Channel Alteration	20	16	20	20	15
Riffle Quality	14	**10**	**9**	**8**	14
Bank Stability L/R*	10/9	6/8	9/9	6/9	10/9
Vegetative Protection L/R*	**5/4**	**1/1**	**3/2**	**1/3**	1/2
Riparian Vegetation L/R*	**1/3**	**1**/10	9/9	**1**/9	10/10
Score	143	123	137	123	143
% of SHAPP Control	100	86	96	86	--

Bold = Notable parameters or scores; *L = Left bank, R = Right bank; each bank has a possible score of 10 points.

3.2 Biological Assessment

Biological assessments include examination of macroinvertebrate communities and water physicochemical constituents. Results are grouped by season and station.

3.2.1 Macroinvertebrate Community Analyses: Primary Metrics

Primary metrics in a biological assessment are used to develop MSCI scores that identify the biological support categorization of stations (MoDNR 2012). MSCI scores, biological support categories, and individual metric values that contributed to the MSCI scores are grouped by season and station.

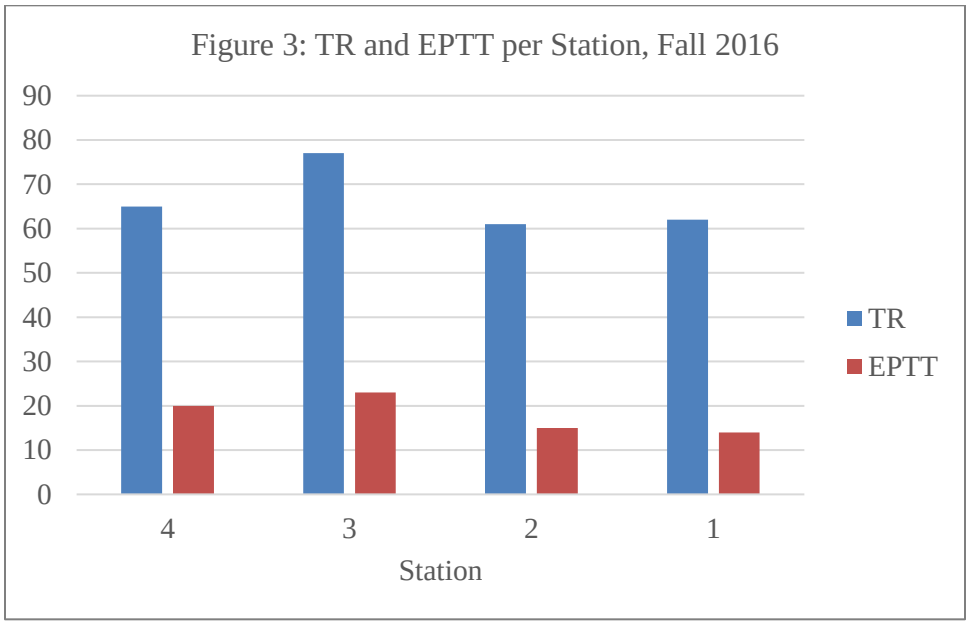
Fall

The biological support category, a measure of a station's ability to support the beneficial use for the protection of aquatic life in fall is presented in Table 4. All four WF stations attained partially supporting MSCI scores of 12 during the fall. All four primary metrics had suboptimal metric scores of 3 at every station. The macroinvertebrate communities of all WF stations had fewer taxa, were less sensitive, were more tolerant to organic pollution or disturbance, and were less diverse than BIOREF streams. Trends among metric values were also apparent. Woods Fork #4 individual metrics such as TR, EPTT, and BI metric values were second highest among stations, and the SDI metric value was the highest among stations. Woods Fork #3 had the highest TR and EPTT metric values (Figure 3), and both were near their respective optimal scoring levels. However, WF #3 also had the highest BI and lowest SDI among WF stations. At WF #2 and WF #1 the TR and EPTT decreased substantially to among the lowest values. The BI trended downward, and the SDI trended upward from WF #2 to WF #1. The BI metric value for WF #1 was equal to the threshold value, and the SDI was among the higher values in WF.

Table 4
Woods Fork Stations, Fall 2016 – Individual Metric Values and Scores, Macroinvertebrate Stream Condition Index Scores (MSCI) and Biological Support Category by Station; Biological Criteria Scoring Table (bottom in gray) Used to Calculate Metric Scores

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	MSCI	Support
Woods Fork #4	16045	**65**$_{(3)}$	**20**$_{(3)}$	**5.9**$_{(3)}$	**3.05**$_{(3)}$	**12**	**P**
Woods Fork #3	16046	**77**$_{(3)}$	**23**$_{(3)}$	**6.1**$_{(3)}$	**2.64**$_{(3)}$	**12**	**P**
Woods Fork #2	16047	**61**$_{(3)}$	**15**$_{(3)}$	**5.8**$_{(3)}$	**2.97**$_{(3)}$	**12**	**P**
Woods Fork #1	16048	**62**$_{(3)}$	**14**$_{(3)}$	**5.0**$_{(3)}$	**3.02**$_{(3)}$	**12**	**P**
Metric Score=5	↔	>79	>25	<5.0	>3.17	20-16	Full
Metric Score=3	↔	79-39	25-13	5.0-7.5	3.17-1.59	14-10	Partial
Metric Score=1	↔	<39	<13	>7.5	<1.59	8-4	Non

BIOREF Scoring Table (bottom) developed from BIOREF streams (*n*=11); TR=Taxa Richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index; (#subscript)=Individual metric score; **Bold**=less than optimum value and score.



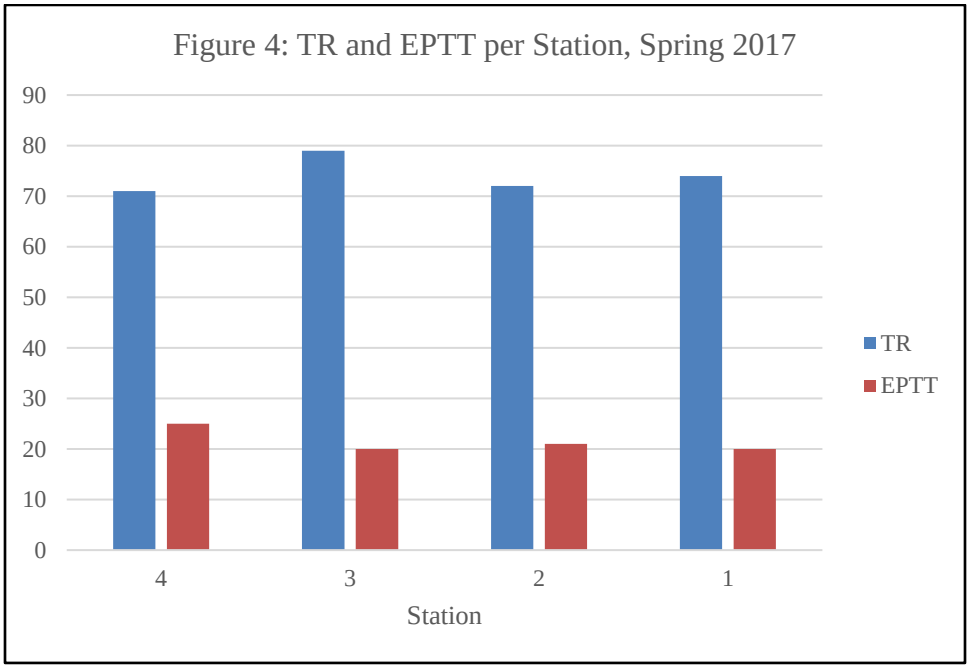
Spring

Spring 2017 MSCI scores and individual metric values are presented in Table 5. Three of the four WF stations attained partially supporting MSCI scores in spring. The most upstream station, WF #4, had a partially supporting MSCI score with suboptimal TR, EPTT, and SDI metric values. The BI metric value was in the optimal scoring range. Together, the metrics suggest the macroinvertebrate community had fewer taxa, was less sensitive and diverse, but was also less tolerant to organic pollution or disturbance. The WF #4 TR and SDI metric values were similar to the most downstream stations, but the EPTT was highest among stations. Woods Fork #3 had the highest TR value, but the EPTT value was among the lower values (Figure 4). Woods Fork #3 had the highest BI value and one of the lower SDI values. The WF #2 and WF #1 TR metric values decreased slightly from the station upstream, and EPTT remained similar to upstream stations. BI values trended downward from WF #3 to WF #1, with the BI value of WF #1 equaling the optimal threshold value for that metric. This BI trend suggests that the communities downstream were slightly less tolerant of organic pollution or disturbance. Unlike the fall samples, none of the TR or EPTT metric values were near their respective optimal thresholds.

Table 5
Woods Fork Stations, Spring 2017 – Individual Metric Values and Scores, Macroinvertebrate Stream Condition Index Scores (MSCI) and Biological Support Category by Station; Biological Criteria Scoring Table (bottom in gray) Used to Calculate Metric Scores

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	MSCI	Support
Woods Fork #4	17020	**71**$_{(3)}$	**25**$_{(3)}$	3.9$_{(5)}$	**2.94**$_{(3)}$	**14**	**P**
Woods Fork #3	17021	**79**$_{(3)}$	**20**$_{(3)}$	**5.4**$_{(3)}$	**2.79**$_{(3)}$	**12**	**P**
Woods Fork #2	17022	**72**$_{(3)}$	**21**$_{(3)}$	**4.9**$_{(3)}$	**3.13**$_{(3)}$	**12**	**P**
Woods Fork #1	17023	**74**$_{(3)}$	**20**$_{(3)}$	**4.7**$_{(3)}$	**2.72**$_{(3)}$	**12**	**P**
Metric Score=5	↔	>95	>31	<4.7	>3.26	20-16	Full
Metric Score=3	↔	95-47	31-15	4.7-7.3	3.26-1.63	14-10	Partial
Metric Score=1	↔	<47	<15	>7.3	<1.63	8-4	Non

BIOREF Scoring Table (bottom) developed from BIOREF streams (*n*=12); TR=Taxa Richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index; (#subscript)=Individual metric score; **Bold**=less than optimum value and score.



3.2.2 Macroinvertebrate Community Analyses: Secondary Metrics

Two secondary metrics were used to further evaluate WF macroinvertebrate communities and how they compared to BIOREF communities. The Percent Sensitive Taxa (PST) metric was used to measure the test station community composition based on sensitivity to organic pollution or disturbance based on BI values for individual taxa. The Dominant Macroinvertebrate Taxa (DMT) identified the similarity or differences in macroinvertebrate communities based on presence and abundance between BIOREF streams and WF stations, as well as among stations.

3.2.2.1 Percent Sensitive Taxa Distribution

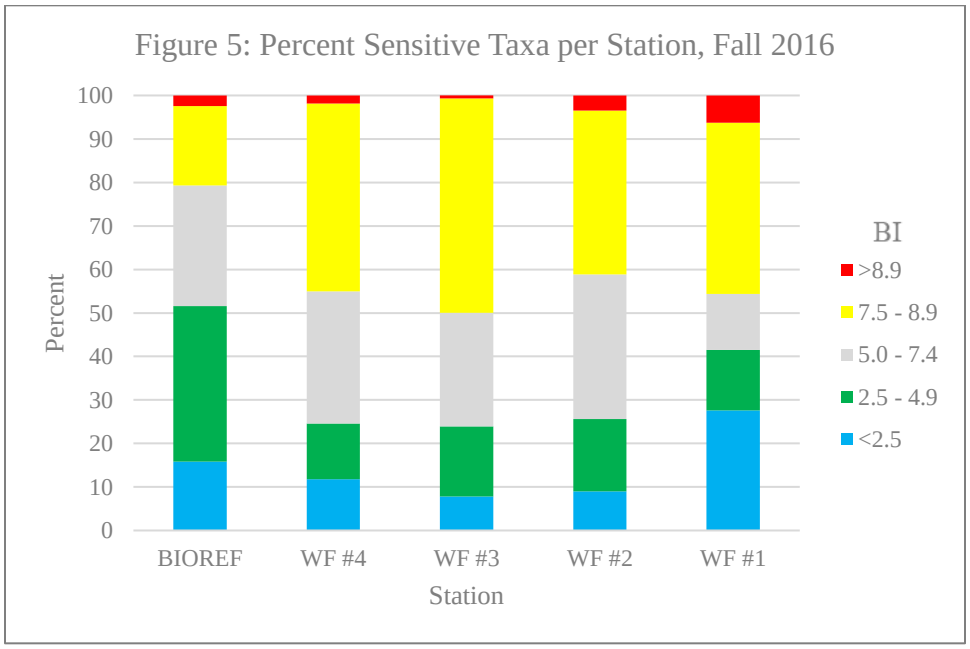
For the PST metric, taxa were grouped into tolerance categories. Three of the five groups were considered of interest. Very sensitive (BI<2.5), sensitive (BI<5.0), and tolerant taxa (BI≥7.5), were identified for WF stations and BIOREF streams (in aggregate). Results are grouped by season and arranged by station.

Fall

PST metric comparisons for fall 2016 are presented in Table 6 and Figure 5. With the exception of WF #1, each of the WF stations had a lower percentage of taxa in the very sensitive and sensitive range compared to BIOREF samples. The percentage of very sensitive taxa at WF #1 was considerably higher than the BIOREFs, but the proportion of WF #1 taxa in the sensitive range was much lower than the BIOREF samples. Interestingly, the percentage of taxa in the very tolerant range was also highest at WF #1, being nearly twice as high as the next nearest station, WF #2.

Table 6
Percent Sensitive Taxa (BI Range) Distribution in Woods Fork Stations and BIOREF Streams of the Ozark/White EDU, Fall 2016

BI Range/ Station	Sample Number	<2.5	2.5 - 4.9	5.0 - 7.4	7.5 - 8.9	>8.9
Woods Fork #4	16045	11.82	12.80	30.32	43.19	1.87
Woods Fork #3	16046	7.80	16.13	26.08	49.33	0.67
Woods Fork #2	16047	8.96	16.63	33.26	37.69	3.46
Woods Fork #1	16048	27.62	13.86	12.91	39.37	6.24
BIOREFs	--	15.81	35.76	27.77	18.22	2.44

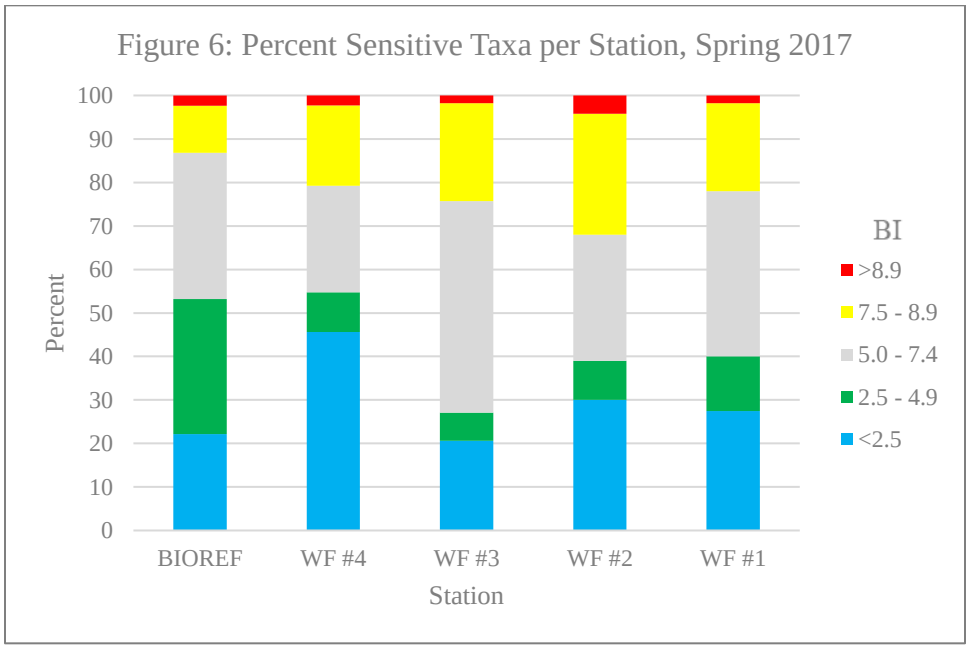


Spring

PST metric comparisons for spring 2017 are presented in Table 7 and Figure 6. At WF #4, very sensitive taxa were roughly twice as abundant as was found in BIOREF samples, but the percent in the sensitive range was a fraction of that in the BIOREFs. When combining the very sensitive and sensitive taxa groups, WF #4 and the BIOREF samples were nearly equal. The remaining WF stations downstream had lower percentages of very sensitive and sensitive taxa (combined groups). Woods Fork #2 had the highest percentage of very tolerant taxa, being roughly double that of every other station and the BIOREFs. Each of the WF stations had a higher percentage of tolerant taxa than the BIOREFs.

Table 7
Percent Sensitive Taxa (BI Range) Distribution in Woods Fork Stations and BIOREF Streams of the Ozark/White EDU, Spring 2017

BI Range/ Station	Sample Number	<2.5	2.5 - 4.9	5.0 - 7.4	7.5 - 8.9	>8.9
Woods Fork #4	17020	45.66	9.06	24.55	18.43	2.30
Woods Fork #3	17021	20.65	6.45	48.63	22.50	1.77
Woods Fork #2	17022	30.01	9.01	28.96	27.84	4.18
Woods Fork #1	17023	27.46	12.60	37.96	20.19	1.78
BIOREFs	--	22.15	31.03	33.63	10.82	2.36



3.2.2.2 Dominant Macroinvertebrate Taxa

The DMT metric lists the top 10 most abundant taxa found in BIOREF streams (in aggregate) and their prevalence at each WF station for fall and spring samples (Tables 8 and 9). The abundance at each station and trends across all stations are presented. Results are grouped by season and station.

Fall

The abundance of BIOREF DMT is presented for each of the fall WF samples in Table 8. The majority of BIOREF DMT were absent or found in much lower abundance at all WF stations. Eight of the BIOREF DMT were absent or found in much lower in abundance at WF #4. Six DMT were absent or ranked lower at WF #3. Six of the 10 BIOREF DMT were absent or reduced at WF #2. Eight of the BIOREF DMT were missing or reduced at WF #1. Overall, WF #3 and WF #2 contained the most DMT in common with BIOREF streams of the EDU.

Trends in the presence and absence of BIOREF DMT were examined across stations in fall samples (Table 8). *Hyalella azteca* was found in common with BIOREF streams at all stations, and they were as much as 3 to 5-times more prevalent at the upstream three stations compared to the BIOREF streams and WF #1. Conversely, *Elimia* spp., *Maccaffertium mediopunctatum*, and *Isonychia bicolor* are BIOREF DMT that were absent from all WF stations. DMT found in common at some stations and absent or ranked lower at others included *Cheumatopsyche* spp., *Psephenus herricki*, and *Optioservus sandersoni*. The remaining BIOREF DMT that included *Dubiraphia* spp. and *Helicopsyche* spp. were absent from some stations, ranked low at others, and were not found in common at any WF station in fall.

Table 8
Dominant Macroinvertebrate Taxa Percentage (and Rank) for BIOREF and Woods Fork Stations, Fall 2016

Dominant Macroinvertebrate Taxa	BIOREF	WF #4	WF #3	WF #2	WF #1
Optioservus sandersoni	9.24 (1)	2.27 (11)	**1.74 (9)**	**4.49 (9)**	1.74 (13)
Psephenus herricki	7.61 (2)	0.73 (21)	**11.65 (3)**	**10.47 (2)**	**7.45 (4)**
Hyalella azteca	5.69 (3)	**20.23 (1)**	**30.79 (1)**	**20.41 (1)**	**3.68 (8)**
Elimia spp.	5.00 (4)	--	--	--	--
Maccaffertium mediopunctatum	4.01 (5)	--	--	--	--
Acarina	3.05 (6)	1.71 (16)	0.27 (30)	**6.62 (5)**	--
Cheumatopsyche spp.	2.86 (7)	**6.99 (4)**	**14.26 (2)**	1.60 (14)	--
Dubiraphia spp.	2.80 (8)	0.49 (27)	--	0.11 (42)	1.06 (17)
Helicopsyche spp.	2.80 (9)	1.95 (13)	0.27 (31)	0.11 (43)	--
Isonychia bicolor	2.80 (10)	--	--	--	--

Rank = numerical position of dominance in that station; -- = absent from sample; **Bold** = Notable percentage or rank.

Spring

The abundance of BIOREF DMT is presented for each of the spring WF samples in Table 9. The majority of BIOREF DMT were absent or found in much lower abundance at all WF stations. Six of the BIOREF DMT were absent or ranked lower at WF #4. Seven BIOREF DMT were absent or much reduced at WF #3, WF #2, and WF #1. Overall, WF #4 contained more DMT in common with BIOREF DMT than the other WF stations, but WF #4 had more DMT that were absent as well. The remaining stations were similar to one another in having the same DMT that were absent or ranked low compared to BIOREF DMT streams.

Trends in the presence and absence of BIOREF DMT were apparent across all WF stations sampled in spring (Table 9). *Cricotopus/Orthocladius* grp., *Leucrocuta* spp., and *Thienemannimyia* grp. were found in common with BIOREF DMT at all WF stations. *Optioservus sandersoni* was in common with BIOREF DMT at WF #4 and ranked low at all other stations downstream. Conversely, *Elimia* spp. and *Ephemerella invaria* were absent from all WF stations. The remaining BIOREF DMT that were absent from some stations or ranked low at others included *Eurylophella bicolor*, *Caenis latipennis*, *Tanytarsus* spp., and *Psephenus herricki*.

Table 9
Dominant Macroinvertebrate Taxa Percentage (and Rank) for BIOREF and Woods Fork Stations, Spring 2017

Dominant Macroinvertebrate Taxa	BIOREF	WF #4	WF #3	WF #2	WF #1
Elimia spp.	12.18 (1)	--	--	--	--
Cricotopus/Orthocladius grp.	6.65 (2)	**9.11 (2)**	**33.92 (1)**	**14.85 (2)**	**27.38 (1)**
Leucrocuta spp.	5.97 (3)	**5.74 (4)**	**8.70 (3)**	**10.35 (4)**	**19.37 (2)**
Ephemerella invaria	5.44 (4)	--	--	--	--
Optioservus sandersoni	3.82 (5)	**3.12 (9)**	0.80 (20)	0.96 (22)	0.32 (35)
Eurylophella bicolor	3.18 (6)	0.13 (47)	0.96 (16)	0.32 (38)	0.40 (30)
Thienemannimyia grp.	3.10 (7)	**4.59 (6)**	**2.79 (6)**	**2.65 (6)**	**1.43 (10)**
Caenis latipennis	2.50 (8)	0.06 (59)	--	--	--
Tanytarsus spp.	2.25 (9)	--	0.72 (23)	0.56 (30)	0.16 (48)
Psephenus herricki	1.84 (10)	--	0.40 (30)	1.85 (12)	0.32 (36)

Rank = numerical position of dominance in that station; -- = absent from sample; **Bold** = Notable percentage or rank

3.2.3 General Water Quality Analyses

Surface water physicochemical constituents were examined for all WF stations (Tables 10 and 11). Constituents were considered notable if they exceeded applicable Missouri WQS (MoDNR 2014) or EPA suggested guidelines for reference conditions (EPA 2000). Results are arranged by season and station.

Fall

Several water constituents were notable at WF #4 in the fall (Table 10). Nitrate+nitrite as N, total nitrogen, and total phosphorus each exceeded their respective EPA suggested concentration (EPA 2000). Turbidity (2.0 NTU) was also slightly higher than the suggested guideline (>1.425 NTU). Discharge was very low at WF #4 (0.9 cfs), and chloride (14.7 mg/L) was slightly higher than all other stations.

At WF #3 the nitrate+nitrite as N concentration was above the EPA suggested guideline (>0.239 mg/L; EPA 2000). Discharge (1.7 cfs) was the highest among stations, and chloride (12.0 mg/L) was slightly higher than the downstream stations.

Nitrate+nitrite as N, total nitrogen, and total phosphorus concentrations all were higher than EPA recommended concentrations (EPA 2000) at WF #2. Discharge was lower at WF #2 than the station upstream, and chloride (11.3 mg/L) was slightly higher than the downstream station.

Several physicochemical water constituents were notable at WF #1, and one violated WQS (MoDNR 2014; Table 10). The nitrate+nitrite as N concentration exceeded the EPA suggested guideline, and dissolved oxygen at WF #1 (3.71 mg/L) was lower than the WQS (<5.0 mg/L; MDNR 2014) and was much lower than other stations. Discharge and chloride were both lowest among all WF stations.

Table 10
Fall 2016 Woods Fork Physicochemical Water Constituents

Station/ Parameter	WF #4	WF #3	WF #2	WF #1
Sample Number	163799	163800	163801	163802
pH (Units)	7.6	7.5	7.7	7.4
Temperature (°C)	17.7	19.2	19.6	19.8
Specific Conductance (µS/cm)	433	417	437	429
Dissolved O_2	8.06	6.94	8.09	**3.71**
Discharge (cfs)	0.9	1.7	0.9	0.1
NFR	<5 ND	<5 ND	<5 ND	<5 ND
Turbidity (NTU)	*2.0*	1.0	<1	1.2
Total Nitrogen	*0.82*	*0.35*	*0.51*	*0.32*
Nitrate+Nitrite as N	*0.88*	*0.36*	*0.50*	*0.33*
Ammonia-N	<0.03 ND	<0.03 ND	<0.03 ND	<0.03 ND
Sulfate	9.26	6.44	8.76	8.65
Chloride	14.7	12.0	11.3	10.1
Total Phosphorus	*0.016*05	<0.01 ND	*0.014*05	<0.01 ND
Calcium	71.5	66.7	69.0	66.2
Magnesium	6.67	8.59	11.2	12.2
Hardness	206	202	218	216

Units mg/L unless otherwise labeled; **Bold**=violation of WQS (MDNR 2014); *Italics* = exceeding EPA (EPA 2000) suggested guidelines: NO_3+NO_2-N >0.239 mg/L; TN >0.289 mg/L; TP >0.006625 mg/L; Turbidity >1.425 NTU.
Subscript qualifiers: 05 = estimated value, detected below the Practical Quantitation Limit; ND = non-detect.

Spring

Several water constituents were notable at WF #4 in the spring (Table 11). Nitrate+nitrite as N, total nitrogen, and turbidity all exceeded EPA suggested guidelines (EPA 2000). Discharge was lowest among stations, and chloride was higher than all downstream stations.

At WF #3 nitrate+nitrite as N, total nitrogen, and turbidity all exceeded their respective EPA suggested guidelines (EPA 2000). Discharge was higher than upstream, and chloride was slightly lower than the upstream station. Woods Fork #3 was the only station where ammonia as N was detected in the spring (Table 11).

Nitrate+nitrite as N and total nitrogen exceeded EPA suggested guidelines (EPA 2000) at WF #2. Discharge was highest among all stations, and chloride was slightly lower than the upstream stations.

Nitrate+nitrite as N was the only nutrient above the EPA suggested guideline (EPA 2000) at WF #1. Discharge was approximately 4 cfs lower than the station upstream. Chloride was present in the lowest concentration among stations.

Table 11
Spring 2017 Woods Fork Physicochemical Water Constituents

Station/ Parameter	WF #4	WF #3	WF #2	WF #1
Sample Number	171917	171918	171919	171920
pH (Units)	7.7	8.0	8.3	7.7
Temperature (°C)	15.3	15.2	15.8	14.1
Specific Conductance (µS/cm)	341	309	311	334
Dissolved O_2	10.93	10.69	11.09	9.45
Discharge (cfs)	6.2	11.3	18.2	14.4
NFR	<5 ND	<5 ND	<5 ND	<5 ND
Turbidity (NTU)	*1.5*	*1.7*	<1	1.2
Total Nitrogen	*1.02*	*0.45*	*0.40*	0.35
Nitrate+Nitrite as N	*0.95*	*0.38*	*0.34*	*0.30*
Ammonia-N	<0.03 ND	0.11	<0.03 ND	<0.03 ND
Sulfate	7.25	6.90	8.13	7.36
Chloride	9.28	8.19	7.74	7.05
Total Phosphorus	<0.01 ND	<0.01 ND	<0.01 ND	<0.01 ND
Calcium	65.1	55.4	55.8	55.5
Magnesium	5.81	7.06	8.10	9.03
Hardness	186	167	173	176

Units mg/L unless otherwise labeled; *Italics* = exceeding EPA (EPA 2000) suggested guidelines: NO_3+NO_2-N >0.239 mg/L; TN >0.289 mg/L; TP >0.006625 mg/L; Turbidity >1.425 NTU. Subscript qualifiers: 05 = estimated value, detected below the Practical Quantitation Limit; ND = non-detect.

3.2.4 Total Metals in Surface Water

Total cadmium (<0.125 µg/L), lead (<0.625 µg/L), and zinc (<0.625 µg/L) were not detected in surface water at any WF station in the spring of 2017. Metals will not be further discussed in this report, but they were analyzed to evaluate possible effects of past mining in the general area.

4.0 Discussion

Stream habitat conditions and biological assessment results are discussed in this section. The ability of each station to support the beneficial use for the protection of aquatic life was evaluated using primary biological metrics. Secondary metrics are also discussed. Notable water quality results are discussed to relate possible effects on the macroinvertebrate community composition at WF.

4.1 Stream Habitat Assessment

According to the SHAPP (MoDNR 2016c), stream habitat quality is considered comparable to the SHAPP control when the test stream is ≥75 percent of the control score. Using that definition, all WF stations were considered comparable to the SHAPP control. However, flow conditions and the presence of excessive alluvium in WF may influence results in this and other sections of this discussion.

When stream habitat assessments were conducted, surface flow was considerably lower at three stations than during reconnaissance in summer. Tyler Gregory (MDC forestry manager at Busiek SF, MDC Southwest Regional Office, Springfield, Missouri) described the extremely low flow condition as "typical" in the stream reaches that include WF #3, WF #2, and WF #1 from August through January. In this study, surface flow at those stations was limited in fall, only visible in small, scattered, low-lying areas of the stream, such as next to outside banks and in deep pockets that resembled pools in the deep alluvium. Water was clearly flowing through these pool-like pockets, indicating the flow was subsurface through interstitial spaces of gravel and pebble-sized rocks. Surface flow was reported to be plentiful in late winter, spring, and summer. Surface flow was much greater and visible over most of the stream channel when the stream was sampled in spring. Given these observations, it is important to expand on factors that may have affected the quality of aquatic habitat in WF.

Although WF #4 was relatively similar to the SHAPP control, three variables affected the habitat score in the fall. The small spring-fed stream did not have deep pools, which contributed to a slightly lower score. Although we found the banks to be very stable within this station, banks were not well vegetated, potentially leaving them vulnerable to erosion. The riparian corridor had little wooded coverage, with pasture on the left bank and sparse woods on the right. The stream had consistent flow from a nearby spring-fed lake overflow.

Channel Flow Status, Riffle Quality, and Vegetative Protection decreased habitat quality available in the fall and resulted in reduced SHAPP scores for WF #3, WF #2, and WF# 1. The wetted channel was very narrow, filling ≤25 percent of the available channel. As such, riffles were short, and runs were scarce due to little surface flow in the available channel. Banks were also not well vegetated at these stations; however, the banks again were relatively stable. The Channel Flow Status and Riffle Quality metrics were influenced by the dry conditions during the fall SHAPP assessment.

Substrate

Woods Fork is considered an alluvial stream, which is characterized by having a considerable amount of sediment, gravel, pebble, or larger-sized material deposited as part of the substrate. Substrate at the three downstream stations consisted of relatively consolidated gravel and pebble-sized rocks (Modified Wentworth Scale in Cummins 1962; Minshall 1984: Appendix B). Interestingly, the instream material was not well embedded; however, the benthic substrate appeared to be generally stable. Substrate interstices were relatively clear and appeared to be good quality habitat for use by macroinvertebrates. The larger size of the substrate likely serves to hold it in place during normal and even higher flow. The substrate particles appeared to have been in place for a considerable time. However, some areas within WF #3, WF #2, and

downstream from WF #1 had massive bar formations of large gravel and pebble-sized rocks on higher banks near bends and at the confluence with Bull Creek (Appendix B). These areas did not contribute much to the SHAPP scores due to their locations either on the high bank or outside of the normal pool, but these conditions do indicate there is a considerable source for alluvium that may be deposited in WF during periods of high flow **(**Appendix B-6 and Appendix D**)**. The substrate was a massive lens of gravel and pebble-sized material that covers the stream and limits accessibility to surface water during periods of lower flow in fall and winter. The excessive alluvium may be due to past and present instream or land uses, and the term "alluvial stream" in this case does not describe a common natural aquatic community described by Jacobson and Primm (1997).

The sources for the alluvium are unclear. Clearing of hill-slopes are not likely to contribute the gravel- or pebble-sized material due to the length of travel to reach the stream; rather, increased runoff of cleared hills into the already cleared lowland valleys with narrow riparian corridors tends to remove gravel-sized material from first and second order streams for deposit downstream (Jacobson and Primm 1997). Woods Fork is a low order stream (Strahler stream order 1-4) with cleared pasture in much of its headwaters (Appendix C), and it tends to flood extensively (Tyler Gregory, MDC Forestry Manager, Busiek SF pers. comm.). The watershed is approximately 41 square miles with numerous elevation changes of as much as 400 feet in many deep valleys. The watershed flow and energy potential from runoff contributes considerable flow in a short period of time into a relatively low order stream, as is evident by frequent and massive flooding. The amount of alluvium deposited on high banks is evidence of considerable flow. Although the banks of each WF station were moderately stable within each study reach, there were many areas outside of the stations where banks appeared to be unstable. For example, the stream corridor downstream from WF #4 to just upstream of WF #3 was mostly in pasture with little or no wooded riparian corridor. This area had what appeared to be unstable banks that may contribute to the bedload downstream.

Clearing of riparian vegetation in first- and second-order valleys can result in headward expansion of the channel network. Incision into non-channeled areas would deliver gravel from storage to streams at an accelerated rate and simultaneously increase conveyance of the channel network, thereby increasing flood peaks downstream (Jacobson and Primm 1997). This hypothesis is supported by a lack of other source areas for gravel and by observations that gravel came from small stream valleys, not off the slopes (Jacobson and Primm 1997). This headward expansion is illustrated in an aerial photograph of WF upstream of the study area (Appendix C). The photograph is of a fescue pasture immediately upstream of US65, which is approximately 1 mile upstream of WF #4. Just south of Woods Fork Road, the main channel is presently a clear and active source for fresh alluvium. Banks in the main channel at that location are deep, loose, and have no vegetation or wooded riparian corridor to retain the material. A second channel (presently a high water channel) is forming approximately 20 to 50 yards to the south of the main channel and can be seen as a line of exposed rock (Appendix C). Both are contributing gravel and pebble-sized material to the bedload downstream in WF. The newly forming channel also represents future contributions and suggests that the energy potential is present and headward expansion is occurring.

Sediment eroded during one phase of land use history may take decades or more to move from hill slopes to valley bottoms and through the alluvial system (Meade 1990; Jacobson and Primm 1997). Even if hydrologic conditions of uplands are improved to decrease runoff and sediment supply, it is likely that the overload of sediment already in transit through stream channels will work counter to riparian recovery processes. Under these conditions, the stabilizing role of riparian vegetation becomes critical (Jacobson and Primm 1997). Woods Fork #4, WF #3, and WF #1 had little wooded riparian corridor in some areas. Future conservation efforts should focus on watershed management to reduce land disturbance and gravel sediments from being deposited into WF (Culler 2010).

Downstream Influences

Other influences downstream, coupled with the potential for massive runoff upstream, may contribute to the energy necessary to add and move the alluvium in WF. Woods Fork is a tributary of Bull Creek (Figure 2), and gravel mining in Bull Creek has the potential to affect stream bed stability in upstream tributaries such as WF. Bull Creek has at least two gravel mining operations downstream from WF that are considered "floodplain pit gravel mines" (Appendix D). The Tri County Sand and Gravel Company, a floodplain pit dug off-stream, and another unnamed mine were evaluated in a previous Bull Creek biological assessment study (MoDNR 2003).

Floodplain gravel mining may affect flood hydraulics by increasing the flow and shortening the conveyance path for floodwaters. This can cause rivers to divert into and through mining pits and result in higher velocities and scour. Erosional processes associated with floodplain pits can result in river channel changes where the river diverts into, and through, gravel mines. These diversions can lead to bed degradation, bank erosion, and channel widening (Ladson and Judd 2014). Instream or floodplain pit gravel mining can increase velocity and create headcuts (degradation) upstream that can deliver excessive amounts of gravel (aggradation) to the stream (Brown and Lyttle 1992; MDC 2009; Ladson and Judd 2010). Headcutting can have major effects for many kilometers upstream from mines (Smith and Patrick 1991; Pringle 1997; Brown et al. 1998). When eroded gravel reaches the enlarged channel, it is deposited as the water slows (Brown et al. 1998). An example of this process is shown by photographs of WF at its confluence with Bull Creek (Appendix B-6 and Appendix D). Aerial photographs in Appendix D show extensive bar formations on Bull Creek that clearly extend upstream into and beyond WF in Bull Creek. Bar formation appears to lessen downstream from the Tri County operation for a distance, and increases moving closer to the unnamed flood pit mine farther downstream near Walnut Shade (Appendix D-6 to D-9).

Floodplain gravel mining can cause changes in the riverine environment, both locally and farther away from the mining site, and in the short and long term (Ladson and Judd 2014). Removal of substrate from stream channels has the most effect on alluvial gravel streams (Resh et al. 1988; Brown and Lyttle 1992). Gravel mining can continue to remove large amounts from a single location, due to fresh deposits being periodically delivered from upstream during high flow events (Brown et al. 1998). If there is a channel avulsion into a pit, an upstream migrating nickpoint can form as the river readjusts its grade (Norman 1998; Hilldale et al. 2005). The pit

essentially becomes a sediment trap, perhaps for decades or longer, significantly affecting rivers in the area of the pit by potentially causing channel incision or increased bank erosion (Kondolf et al. 2002; Hilldale et al. 2005).

Results from the previous MoDNR study on Bull Creek (MoDNR 2003) show potential effects on the macroinvertebrate communities in a station (Bull Creek #4) upstream from the Tri County mine location. The Tri County mine was not in operation in 2002 when this study took place, but as mentioned effects can be long lasting (Culler [2010] noted that the mine was in operation in 2008). The Bull Creek bioassessment report (MoDNR 2003) did not attribute any causes to the low MSCI score at the upstream Bull Creek station; however, instability of the substrate may have affected the station upstream of the mine in Bull Creek, and this may also be the case in WF stations.

Alteration of the stream channel shape by removing a portion of the bed load can have negative effects on stream geometry, including the loss of habitat diversity needed to support macroinvertebrate communities (Brown et al. 1998). Future studies on streams where gravel mining occurs should include monitoring sample locations upstream of gravel mines to account for these potential effects. In addition to upstream effects, gravel mining also can impair water quality and increase downstream fine sedimentation, which may reduce or eliminate aquatic communities (Roell 1999).

4.2 Biological Assessment

This biological assessment included examination of the macroinvertebrate community to determine the ability of WF to support the beneficial use of the protection of aquatic life. Macroinvertebrate community analyses also include examination of primary and secondary biological metrics. Applicable physicochemical water quality constituents are highlighted and discussed.

4.2.1 Macroinvertebrate Community Analyses: Primary Metrics

All WF stations attained partially supporting MSCI scores during both sample seasons. All stations had MSCI scores of 12 in the fall, and the three downstream stations had scores of 12 in the spring. Only WF #4, the spring-fed station with relatively consistent flow, attained a slightly higher suboptimal score of 14 in the spring. Generally, the macroinvertebrate community was not similar to communities found in BIOREF streams of the Ozark/White EDU

Individual metric values exhibited trends that may identify potential types and sources of effects. An elevated BI metric value in the fall and optimal BI in spring suggests there may be an intermittent organic pollution or disturbance effect upstream of or within WF #4. Potential sources of organic pollution or disturbance upstream of or within WF #4 may include, but are not limited to, spill water from the spring pool immediately upstream of the station, septic systems, runoff from the nearby pasture, or from the Highlandville, Missouri, Wastewater Treatment Facility (Permit number: MO-0128091), which discharges to a tributary of WF. At WF #3, TR and BI metric values increased and SDI metric values decreased consistently relative to similar metrics at surrounding stations, suggesting organic pollution/disturbance may have influenced the community. Stations WF #2 and WF #1 generally had TR, BI and SDI metric values nearer

to the upstream station WF #4. Overall trends in metric values suggest the macroinvertebrate community at WF #4 may be intermittently influenced, while WF #3, upstream of Busiek SF, was continuously influenced by organic pollution or disturbance. The immediate land use between WF #4 and WF #3, as mentioned earlier, was pasture used for grazing. Stations WF #2, and WF #1 may be influenced by organic pollution or disturbance based on consistently suboptimal BI metric values, but not to the extent observed at WF #3 as the metric value progressively decreased moving downstream, suggesting the influence was not as prevalent downstream.

It was interesting that spring TR and EPTT metric values were as high as observed, given that most of the stream bed was dry for an extended period over the fall and winter prior to spring sampling. The visible surface areas available for macroinvertebrates to survive over winter were much smaller than what was available for them to use in the spring. The number of survivors (mostly larval forms) from these small pools, riffles, and rootmats alone likely would not be sufficient to recolonize the larger surface area flowing in spring. In spring, metric values downstream were generally similar to the perennial WF #4, which suggests that macroinvertebrate populations persisted in the intermittently dry downstream stations. The taxa richness and EPTT taxa metrics at all stations were similar or increased from fall and spring, suggesting populations were not eliminated over winter. Thus, the drying period did not have an obvious effect on spring populations, as would have been expected if communities had been completely deprived of suitable habitat. Recruitment through life cycles and early stage distribution may have been responsible for some of the spring increase; however, a substantial number of taxa appear to have survived the dry period of fall and winter.

Taxa may have persisted though the dry period because they were adapted to use saturated porous spaces and the hyporheic zone. In the fall, it was apparent that downstream surface flow was generally sparse; however, flow was still observed through small pools 2 to 4 feet below the surface of the alluvium. These accessible pockets with flowing water were surrounded by gravel and pebble sized substrate that was obviously very permeable. The hyporheic zone is saturated interstitial space in the stream bed and adjacent banks (White 1993; Boulton et al. 2010) with groundwater interaction that can be an important refuge (Brunke and Gosner 1997; Malcom et al. 2004; Hose et al. 2005; DiStefano et al. 2009; Woessner 2017) for taxa acclimated to drying in intermittent temperate streams (Wood et al. 2005; Dewson et al. 2007; Lake 2007; Wood et al. 2010). It is likely that the WF macroinvertebrate community, especially downstream in spring, was made up of taxa adapted to using hyporheic flow when the surface of the stream bed is dry.

4.2.2 Macroinvertebrate Community Analyses: Secondary Metrics

Secondary metrics used in this project included the PST and DMT. Observations from the *Macroinvertebrate Bench Sheet Report* (Appendix A) are also included in this section. These metrics were used to examine similarities or differences between BIOREF streams and WF station macroinvertebrate communities, as well as among stations within WF. Comparisons may identify areas of interest and potential influences that may affect WF stations.

Percent Sensitive Taxa

The PST further examines the distribution of taxa in communities based on their sensitivity to organic pollution or disturbance. The PST metric creates sensitivity groups based on BI values of individual taxa. The PST comparison was made between all WF stations and the BIOREF streams, as well as among WF stations to identify longitudinal differences and potential influences. The distribution of sensitive (BI <5.0), tolerant (BI ≥7.5), and very sensitive (BI<2.5) taxa groups were used for comparisons. The PST distribution showed substantial differences between WF and BIOREF streams.

All stations attained partially supporting MSCI scores in both seasons, and all individual metric scores were suboptimal, with the exception of the optimal spring BI score at WF #4. The BI values at WF #3 were consistently among the highest among stations. BI values at WF #2 and WF #1 were consistently lower among stations, but still in the suboptimal range. The BI metric values at WF #1 were equal to their respective threshold values during both seasons. As mentioned, BI metric values may indicate an intermittent organic influence or disturbance upstream of WF #4 and a continuous influence upstream of or within WF #3 with decreasing effects downstream in both seasons.

In fall 2016, the two uppermost stations (WF #4 and WF #3) had the lowest percentage of the combined sensitive taxa categories (BI<5.0). The PST of these stations was approximately half of the BIOREF streams. These stations also had much higher percentages of tolerant taxa (BI>7.5) than the downstream stations. Downstream from WF #3, WF #2 had more combined sensitive taxa and fewer tolerant taxa. Woods Fork #1 had nearly twice the percentage of combined sensitive taxa as each station, nearly that of BIOREF streams, and a percentage of tolerant taxa similar to WF #2. Based on the BI distribution, there appears to be an organic influence as described above with some recovery downstream. However, closer examination shows there were high percentages of very sensitive taxa (BI<2.5) among stations, suggesting other influences may have been important in altering the community composition. It was very interesting that three upstream stations in the fall were able to maintain relatively high percentages of very sensitive taxa, some close to the BIOREF percentage, and WF #1 had nearly three times as many very sensitive taxa than the nearest percentage at other stations and nearly twice that percentage found in BIOREF streams.

In the spring, WF #4 had a higher percentage in the combined sensitive taxa categories (BI<5.0) than all other stations and the BIOREF streams, and it contained the lowest percentage of tolerant taxa among stations, which was slightly higher than BIOREF streams. These observations are consistent with the optimal WF #4 BI metric score in the spring. Station WF #3 had the fewest combined sensitive taxa among stations, approximately half of BIOREF streams, and an increased percentage of tolerant taxa compared to the upstream station. This is also consistent with the BI and may indicate the presence of organic pollutants. Combined sensitive taxa at WF #2 increased from upstream, as did tolerant taxa. Combined sensitive taxa increased slightly at WF #1, and tolerant taxa decreased from the two upstream stations. This pattern seems to be consistent with organic pollution and some recovery downstream from upstream influences.

However, all stations had similar or higher percentages of very sensitive taxa (BI<2.5) than BIOREF streams. The highest percentage of very sensitive taxa was at WF #4, which was over twice that of BIOREF streams; however, WF #4 also had slightly more tolerant taxa than BIOREF streams. Woods Fork #1 and WF #2 also had approximately 21 to 30 percent (RPD, respectively) more very sensitive taxa, and 50 to over 80 percent (RPD, respectively) more tolerant taxa than BIOREF streams. These three stations had the lowest BI metric values and were either within the optimal range (WF #4) or near the optimal range (WF #1 and WF #2). Even WF #3 with the highest BI metric value in spring had a similar percentage of very sensitive taxa compared to BIOREF streams along with the highest percentage of tolerant taxa. The ability of these three stations to maintain the most sensitive taxa group at or well above the reference condition and a higher percentage of tolerant taxa than BIOREF streams identified the presence of a unique community.

If organic influences alone caused the fluctuations in PST, very sensitive taxa should be eliminated before less sensitive taxa. The abundance of very sensitive taxa, together with high percentages of tolerant taxa, suggests the unique macroinvertebrate community was present. The community was made up of taxa that were able to survive different stressful conditions, such as periodic drying. Perhaps this community was adapted to utilize the hyporheic zone during those dry periods.

Dominant Macroinvertebrate Taxa

The DMT metric is another method of quantifying similarities or differences between the macroinvertebrate communities of test streams and BIOREF streams (MoDNR 2012). In the absence of stressors, the DMT of WF stations is expected to be similar to the BIOREF DMT. Absence of BIOREF DMT in WF stations suggests that some stressor(s) may be affecting the population. Comparisons among stations may identify specific areas of interest. The DMT comparisons in this study indicate that WF communities are substantially different than BIOREF stream communities in the Ozark/White EDU.

The number of BIOREF DMT in WF stations was substantially lower than the number in reference streams. The low numbers of BIOREF DMT and the fact that they were present in similar abundance among WF stations suggests that macroinvertebrate communities at all WF stations were not similar to BIOREF stream communities and that some stressor was affecting the community composition. The low number of DMT in common during both seasons suggests the influence is persistent. Fewer DMT downstream is not consistent with recovery from an upstream influence, as suggested earlier by the BI metric values alone, and may identify a unique community as discussed in the PST section.

DMT trends among WF stations suggest macroinvertebrate communities are subject to similar influences. In the fall, three of the DMT found in WF #3 and WF #2 were the same taxa, and two of these taxa were also dominant at WF #1. Three of the missing DMT were also missing from these three stations, which suggests there were similar conditions or potential stressors that similarly affected these taxa. In the spring, WF #3, WF #2, and WF #1 contained only those most common DMT in similar abundance as BIOREF streams. The DMT that were absent and all of the remaining taxa outside the 10 most abundant taxa were the same among these stations as

well. These trends in abundance and presence of BIOREF DMT suggest the three downstream stations may have been affected by similar conditions or stressors that allowed only the most common DMT to occur, while eliminating or limiting other DMT.

Abundance of DMT can also show trends in tolerant and sensitive taxa. Only one BIOREF DMT (*Hyalella azteca*) was found in common at all stations in the fall. Three DMT (*Cricotopus/Orthocladius* grp., *Leucrocuta* spp., and *Thienemannimyia* grp.) were common among all stations in the spring. The abundance of these taxa suggests that they were not substantially influenced by conditions that may have affected the community composition at all WF stations. Conversely, three BIOREF DMT (*Elimia* spp., *Maccaffertium mediopunctatum*, and *Isonychia bicolor*) were absent from all stations in the fall. Two DMT (*Elimia* spp. and *Ephemerella invaria*) were absent from all stations in spring. The implication here is these taxa were sensitive to influences that shaped the macroinvertebrate communities at all WF stations.

Following trends in presence and absence of specific DMT among stations may further identify specific stressors in WF. *Optioservus sandersoni* (riffle beetle) and *Psephenus herricki* (water penny) are obligate aquatic biota for all or much of their life cycles (Merritt et al. 2008). *O. sandersoni* should be present year round as either larvae or adults. In the fall, *O. sandersoni* was present at all four stations, and it was as abundant as BIOREF DMT at WF #3 and WF #2 and slightly lower in abundance (not among the DMT) at WF #1. In the spring, *O. sandersoni* increased to become a DMT at the permanently flowing WF #4, yet it was present in substantially reduced numbers at the downstream stations, perhaps as a result of stressors such as the dry late fall and winter period. *P. herricki* is expected to be present as larvae in streams in the early spring (White and Roughley 2008; Merritt et al. 2008) when sampling occurred, and it may emerge in late spring or early summer. In the fall, *P. herricki* was present, but not among the DMT at WF #4; it was, however, among the DMT at WF #3, WF #2, and WF #1. In the spring, *P. herricki* was absent from WF #4 and not among the DMT at WF #3, WF #2, and WF #1. Increased relative abundance in fall after emergence suggested they were able to recolonize, and the overall decrease from fall to spring suggests they may have been affected by the late fall and winter dry period. Both examples point toward a stressor that was present over the winter, which may have affected other taxa that are not suited to use an alternative habitat such as the hyporheic zone.

<u>Observations: Macroinvertebrate Bench Sheet Report in Both Seasons</u>
The *Macroinvertebrate Bench Sheet Report* (Appendix A) lists all taxa that were present in WF samples. As many as 75 taxa were found in both fall and spring seasons, which suggests habitat was available for them to persist during the dry period. Among them were phreatobites, obligate groundwater dwelling taxa such as *Stygobromus* spp. (amphipod) and *Caecidotea* spp. (a blind and unpigmented isopod). The presence of these taxa indicates that groundwater has contact with the surface stream in WF, which may be a permanent source for flow below and through the stream substrate. Taxa such as *Physella* spp., *Gammarus* spp., *Lirceus* spp., and *Hyalella azteca*, which are dependent on permanent flow, survived the fall dry period and were present in spring samples. Many other taxa that would normally be present in the fall and winter apparently survived the dry surface conditions. The suggestion here is that alternate habitat is available, such as the hyporheic zone, during dry periods for use by taxa that are able to use that habitat.

Poole et al. (2008) suggested that the presence of biota in hyporheic systems can be related to the length of the flow path through the hyporheic zone. As mentioned earlier using the PST, survivors can include normally very sensitive taxa, as well as those that are considered tolerant. Although unique assemblages can survive the dry period in WF, the communities were still not considered optimal as shown by the MSCI results.

Based on observations made during the assessment, excessive alluvium appears to exacerbate low surface flow conditions during dry periods, limiting optimal and available habitats for macroinvertebrate use. These conditions likely have shaped the aquatic community by favoring taxa able to use alternate habitats. The WF communities consisted of both very sensitive and tolerant taxa, and were not similar to those found in BIOREF streams during either season.

4.2.3 Physicochemical Water Quality

Woods Fork physicochemical variables were in compliance with Missouri's WQS (MoDNR 2014), with one exception discussed below. Otherwise, notable results were restricted to EPA suggested nutrient guidelines for reference conditions (EPA 2000), where no Missouri standards presently exist.

Dissolved Oxygen

Dissolved oxygen (DO) at WF #1 (3.71 mg/L) was below the Missouri WQS of 5.0 mg/L (MoDNR 2014) in the fall and much lower than concentrations measured at all other WF stations. The DO measurement was recorded downstream from a small riffle in a small pool (approximately 7 feet in diameter). The pool was surrounded by loose gravel and pebble-sized substrate and contained a relatively large amount of detritus on the substrate. Water was seen flowing into and out of the pool through the thick alluvium. The pools were not stagnant, which would have accounted for a low DO reading if that had been the case. To verify the original reading, two other DO measurements were recorded upstream near the head of the riffle. The results (3.79 mg/L and 4.06 mg/L) were similar to the original measurement. Similar results from outside the pool suggest the low reading in the pool was also not a result of isolated or localized effects, such as decomposition of detritus.

Surface flow in the fall at WF #1 was scattered and only visible in small isolated areas for approximately 150 yards upstream from where DO measurements were recorded. Discharge (0.1 cfs) was the lowest among all stations and nearly one tenth of that of the next lowest flow. Surface flow was not present upstream of the station for at least 0.25 miles. Poole et al. (2008) suggested longer subsurface flow paths through the hyporheic zone may decrease DO concentrations measured on the surface. It was apparent that flow occurred through the interstitial spaces, possibly in association with the hyporheic zone for a considerable distance, thus potentially lowering the DO concentration. The result is consistent with findings of other investigators who have observed acute and/or chronic responses in macroinvertebrate populations due to altered proportions of groundwater and surface water in the hyporheic zone during instances of surface drying. Macroinvertebrate responses will reflect physiological tolerance to water temperature, DO, and pH, which can vary in concert (Brunke & Gonser 1997; Malcolm et al. 2004; Wood et al. 2010).

The time of collection or flow may have affected the DO readings at WF #1. The fall measurement (3.71 mg/L) was the only one recorded in the morning (0840h), and it was by far the lowest concentration among stations. Woods Fork #1 was also sampled in the morning (0900h) in spring, and it was also the lowest measurement among stations. However, the concentration was much higher (9.45 mg/L) than fall, reflecting a difference not related to diel fluctuations. With collection times being almost exactly the same between seasons, the one difference was a substantial increase in discharge from 0.1 cfs in fall to 14.4 cfs in spring. Additionally, fall surface flow was by far the lowest among stations, and spring flow was much lower than the station immediately upstream. The decreased discharge and lower DO readings relative to other stations, suggests substantial flow moves through subsurface routes. It also appears the DO readings were likely related to surface flow and subsequent aeration rather than only diel fluctuations.

Interestingly, similar DO trends were noted in the Department's 2002 Bull Creek study associated with the Tri County floodplain pit sand and gravel mining (MoDNR 2003). Two stations, one upstream and one downstream from the gravel mine, had low DO concentrations (4.0 and 3.5 mg/L), while the two remaining stations had much higher DO concentrations (in the 9 mg/L range). Similar to WF #1, the two stations with low DO readings were sampled in the morning. The report suggested that the low readings may be from diurnal fluctuations, and low DO concentrations seemed to have little obvious effect on the aquatic community composition. Perhaps this was indicative of a unique community that we have noted from metric examinations in WF. As was observed in WF in the spring, the two Bull Creek stations also had much higher DO readings (9.4 and 10.3 mg/L) than in the fall (MoDNR 2003), while discharge was also much higher. Although the conclusion at that time was that diel fluctuations may have affected DO concentrations, low flow and groundwater interaction with surface water may have been a contributor at that stream, which appears to be the case in WF as well. Similar trends in the two streams suggest this fluctuation may be typical in alluvial streams.

Nutrients and Associated Constituents

Although none of the remaining water quality variables were outside Missouri WQS (MoDNR 2014), several nutrients and turbidity values exceeded EPA suggested guidelines (USEPA 2000) in WF stations. Turbidity was consistently above EPA suggested guidelines at WF #4 and intermittently at WF #3. Nitrate+nitrite as N was above suggested guidelines at all WF stations in both seasons. Total nitrogen was above guidelines at WF #4, and WF #2 in the fall, and all WF stations in the spring. Total phosphorus was present in detectable concentrations at WF #4 and WF #2 only in the fall, and no other station or season. Woods Fork #3 was the only station with ammonia in detectable concentrations; however, it was well below the WQS chronic criteria threshold (MoDNR 2014). Nutrients were present at all stations and represented the potential for organic pollution to affect the WF macroinvertebrate community.

Trends in nutrients and associated constituents (here to mean turbidity and chloride) among stations may identify areas of organic influence. Nutrients and associated constituents consistently followed a generally decreasing trend from upstream to downstream. Total nitrogen and nitrate+nitrite as N were consistently over two-times higher at WF #4 than WF #3. In fall

total nitrogen and nitrate+nitrite as N increased slightly at WF #2 and lowered again downstream at WF #1. Chloride also consistently followed a decreasing trend from upstream to downstream. Total phosphorus was only detected in fall, and was higher in concentration at WF #4 and WF #2, as was observed with similar to other nutrients. This indicated there may be an additional, but intermittent, source for organic pollution between WF #3 and WF #2. Woods Fork #1 consistently had the lowest total nitrogen and nitrate+nitrite as N concentrations among WF stations in both seasons. There were no obvious additional areas of influence between WF #2 and WF #1. Trends in these constituents suggest there may be an organic influence upstream or within the upstream station.

There are potential sources for organic input upstream. As mentioned earlier, WF #4 is fed by a large spring-fed lake immediately upstream from the station, which may have been a source for nutrients. Spill water from the lake may be a source of nutrients from fish and aquatic plant production/decomposition (Vanni 2002; McIntryre et al. 2008). Nearby grazing, septic systems, and upstream municipal runoff (i.e. Highlandville WWTF) could be important sources for nutrients and associated constituents, as well. Woods Fork #2 saw an intermittent increase in nutrients potentially caused by input from Camp Creek, a tributary within MDC's Busiek SF located approximately 0.5 miles upstream. However, Camp Creek was not visibly flowing when the samples were collected in the fall. Furthermore, nutrient concentrations were lower in spring when discharge was much greater and obviously supplied in part by Camp Creek.

Historic water quality data from WF were compared to results in this study. In an earlier study of WF, nitrogen values ranged from 0.78 mg/L to 0.90 mg/L, and phosphorus readings ranged from 0.100 mg/L to 0.103 mg/L within the Conservation Opportunity Area, including Busiek SF (Beckman et al. 2002; Culler 2010). All phosphorus levels in the basin were above the MoDNR recommended level of 0.03 mg/L, which were in place at the time. Pastures and septic systems from nearby homes were suggested to be potential causes of elevated nutrients levels in the basin (Beckman et al. 2002; Culler 2010). In this study, total nitrogen ranged from 0.32 to 0.51 mg/L within and downstream from the same area in WF (WF #4 is not within the historically sampled area). Total phosphorus was detected in the area only at WF #2 (0.014 mg/L) and only in the fall. The total nitrogen and total phosphorus concentrations in this study were much lower than those reported by Beckman et al. (2002) and Culler (2010) at the three stations within and downstream from MDC's Busiek SF study area. Our data suggest nutrient concentrations in general have decreased compared to earlier studies.

Discharge

Discharge followed an interesting trend from upstream to downstream in both seasons. Because of surficial runoff and cumulative watershed size, flow in a stream usually increases while progressing downstream. Moving from upstream to downstream in the fall, flow increased between WF #4 and WF #3, decreased at WF #2, and again decreased substantially at WF #1. In the spring, flow was much greater overall and increased from WF #4 to WF #3 and WF #2, before decreasing substantially at WF #1. Complex water flow paths, including losing to and gaining from groundwater, along with flow through very thick layers of alluvium, are likely affecting the amount of surface flow, and the macroinvertebrate communities that can occupy WF.

5.0 Summary

1) Stream habitat was comparable to the stream habitat control. However, excessive alluvium was present at three downstream stations, which limited surface flow.
2) Headward expansion and bank erosion are apparent sources for present and future alluvial deposits in Woods Fork.
3) Past and present instream and flood-pit mining may be responsible for excessive alluvium upstream in Bull Creek and Woods Fork.
4) All stations are partially supporting of the aquatic life protection beneficial use. Organic pollution/disturbance does not appear to be the sole influence on the Woods Fork macroinvertebrate communities.
5) Secondary metrics indicate Woods Fork macroinvertebrate communities are made up of very sensitive as well as tolerant taxa. This community composition is notably different than communities found in BIOREF streams, and considerably different than would be expected if the communities were influenced by organic pollution or disturbance alone. The assemblage appears to be adapted to using alternative habitats such as substrate interstices in the hyporheic zone during periodic drying of the surface stream.
6) Dissolved oxygen was below Missouri WQS at WF #1 in the fall, perhaps due to length of travel through the alluvium in the hyporheic zone and interaction with groundwater.
7) Nutrients and/or associated constituents exceeded EPA suggested guidelines for reference streams (EPA 2000) at all Woods Fork stations; however, nutrient concentrations did not appear to be a substantial influence on the macroinvertebrate communities in Woods Fork.
8) Nutrient concentrations in Woods Fork were lower than historic data.

6.0 Conclusions

1) Stream habitat quality at Woods Fork will be comparable to the stream habitat controls.

   This hypothesis was not rejected. Stream habitat at all Woods Fork stations was considered to be comparable to the stream habitat control. However, a thick layer of alluvium covered the stream bottom, banks, and bars at the three downstream stations, apparently deposited by high flow events. Excessive alluvium appears to have reduced or eliminated surface flow in much of Woods Fork during the fall and winter.

2) Macroinvertebrate Stream Condition Index (**MSCI**) scores will indicate that Woods Fork is fully supporting of the AQL beneficial use, and individual biological metric values will be within the optimum scoring range of wadeable/perennial reference stream biological criteria during the 2016 and 2017 seasons.

   This hypothesis was rejected. All Woods Fork stations were partially supporting of the beneficial use during both sample seasons. All individual metric values (except BI at WF #4 in spring) were outside their optimal scoring ranges at all Woods Fork stations in both seasons. The BI metric value trends did not clearly indicate organic pollution/disturbance was the obvious contributor to the changes in metric values in Woods Fork stations.

3) Secondary metrics (Percent Sensitive Taxa and Dominant Macroinvertebrate Taxa composition) will indicate that Woods Fork macroinvertebrate communities are similar to communities in biological criteria reference (**BIOREF**) streams and among stations.

   This hypothesis was rejected. The PST and DMT compositions suggested WF communities were consistently different from BIOREF stream communities. The PST and DMT also suggested WF communities were unique and different from communities that are affected by organic pollution.

4) Physicochemical water quality constituents will be within acceptable limits as specified in Missouri's Water Quality Standards (**WQS**; MoDNR 2014) and will not be notable when compared to other suggested guidelines for reference conditions (EPA 2000).

   This hypothesis was rejected. The DO was below WQS at WF #1 in fall, possibly due to lengthy subsurface flow through a hyporheic zone that may be low in oxygen. Secondly, nutrients and associated constituents were present and exceeded EPA suggested guidelines (EPA 2000) at all stations. However, nutrient trends did not follow the BI trends closely, suggesting organic pollution was not an obvious contributor to macroinvertebrate community effects observed in WF.

7.0 Recommendations

1. Future conservation efforts should focus on watershed management to reduce land disturbance and gravel sediments from being deposited into WF (Culler 2010).

2. Future studies on streams with gravel mining activity should include sampling locations upstream of gravel mines to account for these potential effects.

3. Long-term DO studies should be conducted using data loggers to measure fluctuations at all stations in this alluvial stream to assess compliance with the Missouri WQS.

4. Nutrients and associated constituents should be periodically monitored at all stations to determine patterns, compliance with Missouri WQS, comparison with suggested guidelines, and identify potential sources.
5.

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Appendix A

Macroinvertebrate Bench Sheet Report: Woods Fork, Christian County, Fall 2016 and Spring 2017. Grouped by Season and Station, Upstream to Downstream.

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [16045], Station #4, Sample Date: 10/3/2016 10:40:00 AM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	8	2	11
AMPHIPODA			
Crangonyx			3
Gammarus	8	3	13
Hyalella azteca		41	208
ARHYNCHOBDELLIDA			
Erpobdellidae	-99		
BASOMMATOPHORA			
Menetus			1
Physella			2
COLEOPTERA			
Dubiraphia		1	5
Optioservus sandersoni	24	4	
Psephenus herricki	8	1	
Stenelmis	1		
DECAPODA			
Faxonius neglectus	1	1	2
DIPTERA			
Ablabesmyia	1	1	
Ceratopogoninae	2	2	
Corynoneura		1	1
Cricotopus/Orthocladius	4		2
Hemerodromia	1		
Labrundinia		1	
Microtendipes			1
Myxosargus			1
Parametriocnemus	1		
Paratendipes		3	1
Polypedilum aviceps	3	1	
Polypedilum flavum	1		
Polypedilum illinoense grp			1
Polypedilum scalaenum grp		5	
Rheotanytarsus	2	1	3
Stempellinella	13	25	7
Tabanus		2	
Tanytarsus	29	16	9
Thienemanniella			1
Thienemannimyia grp.	6	9	5
Tipula	1		
Zavrelimyia		5	1

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [16045], Station #4, Sample Date: 10/3/2016 10:40:00 AM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
EPHEMEROPTERA			
Acerpenna	61		
Baetis	4		
Caenis latipennis		2	
Diphetor	36		3
Eurylophella	1	11	2
Leucrocuta	16		
Maccaffertium bednariki	1		
Maccaffertium modestum	23		
Paraleptophlebia	44	46	5
Stenacron	8	9	1
Stenonema femoratum	1	28	6
ISOPODA			
Lirceus	88	48	30
LUMBRICINA			
Lumbricina	-99	3	
LUMBRICULIDA			
Lumbriculidae		2	6
MEGALOPTERA			
Nigronia serricornis	1		
ODONATA			
Boyeria			-99
Calopteryx		1	6
Gomphidae	1		
Hagenius brevistylus		1	
Stylogomphus albistylus		1	-99
PLECOPTERA			
Agnetina capitata	7		
Capniidae	2		
Leuctra			1
TRICHOPTERA			
Ceratopsyche morosa grp	1		
Cheumatopsyche	85		1
Chimarra	7		
Helicopsyche	20	1	3
Polycentropus	7	15	3
Triaenodes			4
TRICLADIDA			
Planariidae	48	3	2
TUBIFICIDA			

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [16045], Station #4, Sample Date: 10/3/2016 10:40:00 AM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Tubificidae		3	5

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [16046], Station #3, Sample Date: 10/3/2016 12:50:00 PM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	3		1
AMPHIPODA			
Crangonyx		2	3
Gammarus	-99		
Hyalella azteca		3	457
Stygobromus	1	1	
ARHYNCHOBDELLIDA			
Erpobdellidae	-99		
BASOMMATOPHORA			
Menetus			22
Physella			4
COLEOPTERA			
Optioservus sandersoni	20	6	
Psephenus herricki	168	6	
Scirtidae			10
DECAPODA			
Faxonius neglectus	3	3	-99
DIPTERA			
Antocha	1		
Ceratopogoninae	4		
Chironomidae	1	1	1
Chironomus		1	
Corynoneura	1		
Cricotopus bicinctus	1		
Cricotopus/Orthocladius	26		5
Dicrotendipes			5
Forcipomyiinae	1		
Hemerodromia	1		
Labrundinia			1
Micropsectra	4	3	10
Microtendipes			1
Paratanytarsus			1
Paratendipes		11	2
Phaenopsectra		1	
Polypedilum aviceps	7		
Polypedilum flavum	1		
Polypedilum illinoense grp			1
Rheocricotopus	1		
Rheotanytarsus	5		
Stempellinella	1	4	2

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [16046], Station #3, Sample Date: 10/3/2016 12:50:00 PM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Stenochironomus			1
Tanytarsus	6		
Thienemanniella	2		
Thienemannimyia grp.	10	12	1
Tipula	1		
Tribelos		1	
Zavrelimyia		1	
EPHEMEROPTERA			
Acerpenna	1		
Baetis	10		
Choroterpes		3	
Diphetor	15		
Eurylophella	2	1	
Heptageniidae		10	
Leptophlebiidae	8	65	1
Leucrocuta	10		
Maccaffertium mediopunctatum	-99		
Maccaffertium pulchellum	3	2	
Maccaffertium vicarium	3		
Procloeon		1	
Stenacron	11	15	
Stenonema femoratum	3	109	
HEMIPTERA			
Gerris		-99	
Microvelia	1	1	3
ISOPODA			
Lirceus	40	32	9
LUMBRICINA			
Lumbricina		1	
MEGALOPTERA			
Sialis			-99
NEOTAENIOGLOSSA			
Elimia		-99	-99
ODONATA			
Argia		3	
Boyeria			-99
Calopteryx			4
Gomphidae	2		
PLECOPTERA			
Acroneuria	-99		
Agnetina capitata	3		

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [16046], Station #3, Sample Date: 10/3/2016 12:50:00 PM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Capniidae	2		
Perlidae		1	
TRICHOPTERA			
Ceratopsyche morosa grp	2		
Cheumatopsyche	213		
Helicopsyche	3		1
Polycentropus		8	1
Triaenodes			1
TRICLADIDA			
Planariidae	29	3	2
TUBIFICIDA			
Tubificidae		2	
VENEROIDA			
Pisidiidae			1

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [16047], Station #2, Sample Date: 10/3/2016 2:40:00 PM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	3		59
AMPHIPODA			
Crangonyx	2		2
Gammarus	3	4	
Hyalella azteca		3	188
BASOMMATOPHORA			
Ancylidae		1	
Physella			1
BRANCHIOBDELLIDA			
Branchiobdellida		4	
COLEOPTERA			
Dubiraphia			1
Optioservus sandersoni	38	1	3
Psephenus herricki	89	8	1
Stenelmis	1	1	
DECAPODA			
Faxonius neglectus	4	2	-99
DIPTERA			
Ablabesmyia	1	5	
Ceratopogoninae	1	2	
Chironomidae	2		
Chironomus		5	
Cricotopus/Orthocladius	30	1	3
Diptera	1		
Hemerodromia	1		
Hexatoma		1	
Micropsectra	5	1	
Microtendipes		1	
Nilotanypus	1		
Paratanytarsus			2
Paratendipes		76	
Phaenopsectra	1	8	
Polypedilum illinoense grp	1		1
Polypedilum scalaenum grp		2	
Rheotanytarsus	2	1	
Stempellinella	2	4	
Tanytarsus	28	10	5
Thienemanniella	1		
Thienemannimyia grp.	18		1
Tipula			1

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [16047], Station #2, Sample Date: 10/3/2016 2:40:00 PM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Zavrelimyia		1	
EPHEMEROPTERA			
Acentrella	1		
Caenis anceps	1		
Eurylophella	1	2	
Leptophlebiidae	1	51	
Leucrocuta	14	2	
Maccaffertium vicarium	1		
Stenacron	1	10	
Stenonema femoratum	7	63	1
HEMIPTERA			
Sigara			2
ISOPODA			
Caecidotea (Blind & Unpigmented)		3	
Lirceus	10	7	3
LUMBRICINA			
Lumbricina	2	13	
LUMBRICULIDA			
Lumbriculidae	1		
NEOTAENIOGLOSSA			
Elimia			-99
ODONATA			
Argia	1		
Boyeria			-99
Gomphidae	1		
PLECOPTERA			
Acroneuria	4		
Leuctridae	2		1
TRICHOPTERA			
Cheumatopsyche	13		2
Helicopsyche	1		
Hydroptila	1		
Polycentropus	2	4	1
Pycnopsyche			-99
TRICLADIDA			
Planariidae	52		1
TUBIFICIDA			
Tubificidae		8	

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [16048], Station #1, Sample Date: 10/4/2016 8:45:00 AM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
AMPHIPODA			
Crangonyx	31	6	7
Gammarus	13	4	
Hyalella azteca		2	36
Stygobromus	3		
ARHYNCHOBDELLIDA			
Erpobdellidae	1	-99	
BASOMMATOPHORA			
Ancylidae			1
BRANCHIOBDELLIDA			
Branchiobdellida			2
COLEOPTERA			
Dubiraphia			11
Ectopria nervosa		-99	
Helichus lithophilus	1		
Hydrophilidae			1
Optioservus sandersoni	6	11	1
Psephenus herricki	58	18	1
Scirtidae			1
DECAPODA			
Faxonius neglectus	20	27	10
DIPTERA			
Ablabesmyia	1	1	
Anopheles			1
Chironomidae		1	
Chironomus		2	
Corynoneura	3		
Cryptochironomus		1	
Dicrotendipes			1
Diptera		1	
Hemerodromia		2	
Hexatoma	-99		
Labrundinia	2		
Microtendipes		5	
Natarsia	1		
Nilotanypus	7		
Parametriocnemus		1	
Paratendipes	1	1	
Polypedilum scalaenum grp			1
Stempellinella	1	4	

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [16048], Station #1, Sample Date: 10/4/2016 8:45:00 AM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Tanytarsus	5	6	
Thienemanniella	3		
Thienemannimyia grp.	10	3	1
Zavrelimyia	6	1	6
EPHEMEROPTERA			
Baetis	6		
Centroptilum			1
Fallceon	2		
Leucrocuta	125	7	
Maccaffertium vicarium		2	
Paraleptophlebia	37	40	5
Procloeon		3	1
Stenacron	4	3	
Stenonema femoratum	18	50	1
HEMIPTERA			
Microvelia			10
ISOPODA			
Caecidotea (Blind & Unpigmented)	25	4	1
Lirceus	107	75	19
LUMBRICINA			
Lumbricina	1	6	1
LUMBRICULIDA			
Lumbriculidae	1	2	1
ODONATA			
Argia	1	1	
Boyeria			2
Stylogomphus albistylus		5	
PLECOPTERA			
Acroneuria	6	2	
Leuctra	12	13	10
Neoperla	1		
Perlinella ephyre	1		
TRICHOPTERA			
Polycentropus	14	16	
TRICLADIDA			
Planariidae	1	4	1
TUBIFICIDA			
Limnodrilus hoffmeisteri			11
Tubificidae	3		20

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [17020], Station #4, Sample Date: 4/12/2017 11:25:00 AM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	7	5	
AMPHIPODA			
Crangonyx	1	10	1
Gammarus	10	2	4
Hyalella azteca		4	50
Stygobromus		2	
ARHYNCHOBDELLIDA			
Erpobdellidae	3	-99	
BASOMMATOPHORA			
Menetus			1
Physella	4	-99	9
COLEOPTERA			
Dubiraphia		1	1
Dytiscidae		6	
Dytiscus		1	
Optioservus sandersoni	44	5	
DECAPODA			
Faxonius neglectus	-99	1	-99
DIPTERA			
Ablabesmyia		7	
Ceratopogoninae	1	1	
Chironomidae	1		
Clinocera	12		
Corynoneura		1	1
Cricotopus/Orthocladius	77	37	29
Cryptochironomus		1	
Dicrotendipes		22	6
Eukiefferiella	9		1
Hydrobaenus			1
Labrundinia			1
Micropsectra	282	115	78
Neozavrelia			1
Nilotanypus	2		2
Parakiefferiella			1
Paratanytarsus		10	26
Paratendipes		5	
Polypedilum scalaenum grp		10	1
Psectrocladius		2	2

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [17020], Station #4, Sample Date: 4/12/2017 11:25:00 AM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Rheocricotopus			1
Rheotanytarsus	4	3	1
Stempellinella		1	
Sympotthastia		1	
Thienemanniella			5
Thienemannimyia grp.	31	29	12
Zavrelimyia		1	
EPHEMEROPTERA			
Acentrella	5		
Acerpenna	29	16	6
Baetis	2	1	
Caenis latipennis		1	
Diphetor	40	2	4
Eurylophella bicolor		1	1
Leucrocuta	41	48	1
Maccaffertium modestum	-99	4	
Maccaffertium pulchellum	1		
Paraleptophlebia	21	14	
Stenacron		17	1
Stenonema femoratum		7	1
ISOPODA			
Lirceus	53	26	15
LUMBRICINA			
Lumbricina	1	7	
LUMBRICULIDA			
Lumbriculidae		11	1
ODONATA			
Gomphidae	1	2	
PLECOPTERA			
Agnetina capitata	2		
Amphinemura	2	1	1
Chloroperlidae	3	1	
Isoperla	1	1	
Leuctridae	34	43	4
Perlesta	1	1	
TRICHOPTERA			
Cheumatopsyche	6		
Chimarra	8		
Helicopsyche	12	2	9
Hydroptila	3	1	3

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [17020], Station #4, Sample Date: 4/12/2017 11:25:00 AM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Oxyethira			2
Polycentropus	-99	4	2
Rhyacophila	2		
TRICLADIDA			
Planariidae	22	4	
TUBIFICIDA			
Limnodrilus hoffmeisteri		2	
Tubificidae		5	

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [17021], Station #3, Sample Date: 4/12/2017 1:00:00 PM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	13	2	1
AMPHIPODA			
Crangonyx	1	9	4
Hyalella azteca			28
BASOMMATOPHORA			
Ancylidae			1
Physella	1		3
BRANCHIOBDELLIDA			
Branchiobdellida			4
COLEOPTERA			
Dytiscidae		1	
Optioservus sandersoni	6	4	
Psephenus herricki	3	2	
DECAPODA			
Faxonius neglectus	1		2
DIPTERA			
Ablabesmyia		8	1
Antocha	2		
Brillia			1
Cardiocladius	1		
Ceratopogoninae			1
Chironomidae	2		1
Constempellina	1		
Corynoneura	1		1
Cricotopus bicinctus	4		4
Cricotopus trifascia	1		
Cricotopus/Orthocladius	274	58	93
Dicrotendipes		4	6
Diptera	1		
Eukiefferiella	9		1
Hemerodromia		1	
Micropsectra	49	12	31
Microtendipes		2	
Nilotanypus	1		
Parametriocnemus	2		
Paratanytarsus	1	8	10
Paratendipes			6
Polypedilum flavum		2	
Polypedilum illinoense grp			1
Polypedilum scalaenum grp		1	

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [17021], Station #3, Sample Date: 4/12/2017 1:00:00 PM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Potthastia	1	2	1
Pseudosmittia			1
Rheotanytarsus	1		
Simulium	6		
Stempellinella		1	
Stenochironomus			1
Sympotthastia	15	4	16
Tanytarsus		3	6
Thienemanniella	8		3
Thienemannimyia grp.	9	21	5
Tribelos			1
Zavrelimyia		2	2
EPHEMEROPTERA			
Acentrella	28		
Baetis	11		3
Diphetor	1		
Eurylophella bicolor		2	10
Leucrocuta	84	23	2
Maccaffertium vicarium		-99	
Paraleptophlebia	7	12	
Stenacron	1	7	
Stenonema femoratum	9	34	1
ISOPODA			
Caecidotea (Blind & Unpigmented)	8		
Lirceus	39	74	26
LEPIDOPTERA			
Crambidae			1
LUMBRICINA			
Lumbricina	1	2	
LUMBRICULIDA			
Lumbriculidae			1
NEOTAENIOGLOSSA			
Elimia			-99
ODONATA			
Calopteryx			-99
Stylogomphus albistylus			1
PLECOPTERA			
Acroneuria	4	2	6
Amphinemura	5		
Isoperla	3	-99	

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [17021], Station #3, Sample Date: 4/12/2017 1:00:00 PM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Zealeuctra	1	12	6
TRICHOPTERA			
Agapetus	1		
Cheumatopsyche	-99		
Helicopsyche		1	
Polycentropus	1	3	
Pycnopsyche			-99
Rhyacophila	-99		
Triaenodes			1
TRICLADIDA			
Planariidae	2	5	5
TUBIFICIDA			
Enchytraeidae	1		1
Limnodrilus hoffmeisteri		1	2
Tubificidae			4
VENEROIDA			
Pisidiidae			1

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [17022], Station #2, Sample Date: 4/12/2017 2:05:00 PM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	3	5	1
AMPHIPODA			
Gammarus	6	6	19
Hyalella azteca		3	15
Stygobromus		3	
BASOMMATOPHORA			
Physella			4
COLEOPTERA			
Dytiscidae		1	
Microcylloepus pusillus			1
Optioservus sandersoni	4	2	6
Psephenus herricki	7	16	
DECAPODA			
Faxonius neglectus	1	-99	1
DIPTERA			
Ablabesmyia		8	1
Ceratopogoninae		2	
Chironomidae		4	1
Chironomus		5	
Clinocera	2		
Corynoneura		1	
Cricotopus bicinctus			1
Cricotopus/Orthocladius	127	10	48
Cryptochironomus		2	
Dicrotendipes		10	4
Eukiefferiella	4		1
Hemerodromia	1		
Limnophila		-99	
Micropsectra	73	29	39
Paratanytarsus	1	7	22
Paratendipes		6	
Polypedilum aviceps	3		2
Polypedilum flavum	1		
Polypedilum scalaenum grp		2	
Potthastia		1	
Psectrocladius		1	
Rheocricotopus	1		
Rheotanytarsus			3
Simulium	10		
Stictochironomus		3	

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [17022], Station #2, Sample Date: 4/12/2017 2:05:00 PM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Sympotthastia	11		8
Tanytarsus	1	2	4
Thienemanniella	2		2
Thienemannimyia grp.	16	12	5
Zavrelimyia		9	1
EPHEMEROPTERA			
Acentrella	28		
Centroptilum			3
Ephemerella invaria	-99	-99	
Eurylophella bicolor		3	1
Leptophlebia	1	8	1
Leucrocuta	111	17	1
Paraleptophlebia	13	9	
Plauditus	4		
Stenacron		16	
Stenonema femoratum	4	24	
ISOPODA			
Caecidotea (Blind & Unpigmented)	1		
Lirceus	82	12	113
LUMBRICINA			
Lumbricina	6		
LUMBRICULIDA			
Lumbriculidae		4	
ODONATA			
Argia		1	
Stylogomphus albistylus		-99	
PHARYNGOBDELLIDA			
Hirudinidae	-99	-99	
PLECOPTERA			
Acroneuria	1	-99	
Alloperla	37		
Amphinemura	5		9
Isoperla	10		1
Leuctridae	6	9	2
Perlesta	2		9
TRICHOPTERA			
Helicopsyche			1
Hydroptila	1		2

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [17022], Station #2, Sample Date: 4/12/2017 2:05:00 PM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Polycentropus	6	7	
Pycnopsyche			-99
Rhyacophila	2		
TRICLADIDA			
Planariidae	23		10
TUBIFICIDA			
Limnodrilus hoffmeisteri		4	
Tubificidae		22	
VENEROIDA			
Corbicula		1	

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [17023], Station #1, Sample Date: 4/13/2017 9:05:00 AM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina		3	1
AMPHIPODA			
Crangonyx			4
Hyalella azteca			1
Stygobromus	3		
BRANCHIOBDELLIDA			
Branchiobdellida			1
COLEOPTERA			
Dytiscidae		2	
Hydrophilus			-99
Optioservus sandersoni	2	1	1
Psephenus herricki	2	2	
Stenelmis		1	
DECAPODA			
Faxonius neglectus		-99	
Faxonius virilis	-99		-99
DIPTERA			
Ceratopogoninae		8	
Chaetocladius	2		
Chrysops		1	
Clinocera	5	2	
Corynoneura		2	3
Cricotopus/Orthocladius	203	16	126
Dicrotendipes	1	18	4
Diptera		1	
Eukiefferiella	9		3
Hexatoma	1		
Micropsectra	9	7	8
Microtendipes		3	
Orthocladius (Euorthocladius)	4		
Parakiefferiella		1	
Paraphaenocladius	8		
Paratanytarsus	4	4	7
Paratendipes	1	7	1
Polypedilum aviceps			2
Polypedilum flavum			3
Polypedilum illinoense grp	1		2
Polypedilum scalaenum grp		1	
Polypedilum tritum	2		
Potthastia	5	2	1

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [17023], Station #1, Sample Date: 4/13/2017 9:05:00 AM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Prosimulium	1		
Rheotanytarsus	1		1
Simulium	4		8
Smittia		1	
Stempellinella		1	
Sympotthastia	6		4
Tanytarsus		2	
Thienemanniella	4		6
Thienemannimyia grp.	3	9	6
Zavrelimyia		1	1
EPHEMEROPTERA			
Acentrella	31		3
Baetis	1		
Centroptilum	1		10
Diphetor	1		
Eurylophella bicolor		1	4
Leptophlebia	1	2	
Leptophlebiidae	2	6	2
Leucrocuta	180	63	1
Plauditus	5		
Stenonema femoratum	2	5	
ISOPODA			
Caecidotea (Blind & Unpigmented)	14	4	2
Lirceus	65	70	47
LUMBRICINA			
Lumbricina	10	2	
LUMBRICULIDA			
Lumbriculidae		5	
ODONATA			
Gomphidae	1		
PHARYNGOBDELLIDA			
Hirudinidae	1		-99
PLECOPTERA			
Acroneuria	-99		
Amphinemura	25		37
Chloroperlidae	2	7	
Isoperla	35		5
Leuctridae		5	
Perlesta	3		3

Aquid Invertebrate Database Bench Sheet Report
Woods Fork [17023], Station #1, Sample Date: 4/13/2017 9:05:00 AM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
TRICHOPTERA			
Agapetus	2		
Cheumatopsyche			1
Hydroptila			5
Polycentropus	3	4	
TRICLADIDA			
Planariidae	6	1	
TUBIFICIDA			
Enchytraeidae			1
Tubificidae		2	

Appendix B

Photographs of Woods Fork Stations

Woods Fork #4

Woods Fork #3 near Busiek State Forest north boundary looking upstream, fall 2016

Woods Fork #3 near Busiek State Forest boundary looking upstream, spring 2017

Woods Fork #3 near Busiek State Forest boundary looking downstream, fall 2016

Woods Fork #3 near Busiek State Forest boundary looking downstream, spring 2017

Woods Fork #2 looking downstream, spring 2017

Woods Fork #2 looking upstream, spring 2017

Woods Fork #1 near confluence with Bull Creek looking upstream, spring 2017
(This area mostly dry except for one pool and 10 foot riffle section in fall 2016).

Woods Fork #1 just upstream of confluence with Bull Creek, spring 2017

Looking downstream on Bull Creek (left) at the confluence with
Woods Fork (on right, beyond gravel/pebble deposits)

Appendix C

Images of Woods Fork Upstream and Downstream US65
Courtesy Google Earth Pro

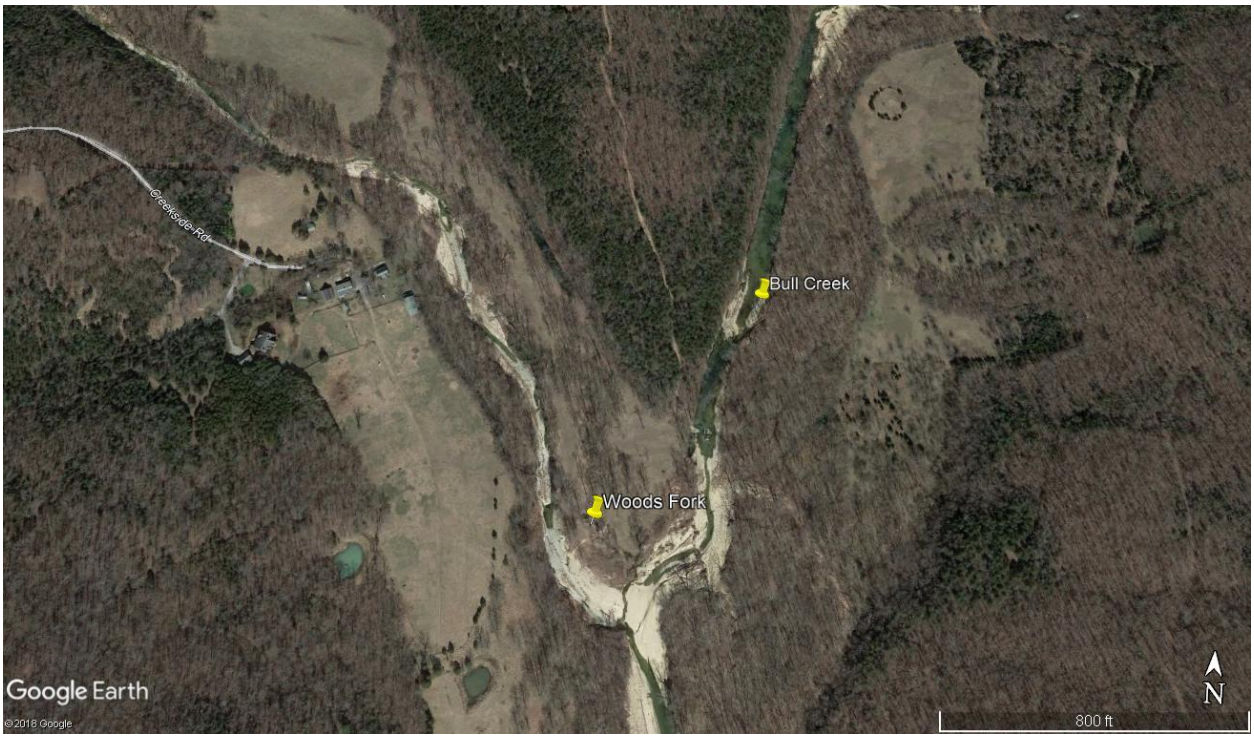
Woods Fork Upstream of US65

Woods Fork Downstream from US65

Appendix D

Images of Bull Creek from Woods Fork Confluence to Tri County Sand and Gravel Mine and Unnamed Gravel Mine near Walnut Shade, MO (Upstream to Downstream)

Courtesy Google Earth Pro


Creekside Rd
Bull Creek
Woods Fork
Google Earth
©2018 Google
800 ft
N

Google Earth
©2018 Google
800 ft
N

Google Earth
© 2018 Google
N
800 ft

Tabor Hollow Rd
H
Dry Hollow Rd
Strawberry Dr
Google Earth
© 2018 Google
N
900 ft

Dry Hollow Rd
Ranch Rd
Google Earth
© 2018 Google
900 ft
N

Ranch Rd
Dry Hollow Rd
Cambridge Rd
Seven Pines Dr
Google Earth
© 2018 Google
900 ft
N

Seven Pines Dr
Cambridge Rd
Rounds Mountain Rd
Google Earth
© 2018 Google
900 ft
N

Cambridge Rd
Rounds Mountain Rd
Google Earth
© 2018 Google
900 ft
N

Reems Mountain Rd
Google Earth
© 2018 Google
900 ft
N

Reems Mountain Rd
Tri County Sand and Gravel Mine
Google Earth
© 2018 Google
1000 ft
N

Goodnight Hollow Rd
Round Mountain Rd
Franklin Rd
Google Earth
© 2016 Google
N
900 ft

Round Mountain Rd
Franklin Rd
Google Earth
© 2016 Google
N
900 ft

Google Earth
© 2018 Google
900 ft
N

Elizabeth Rd
Google Earth
© 2018 Google
900 ft
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Elizabeth Rd
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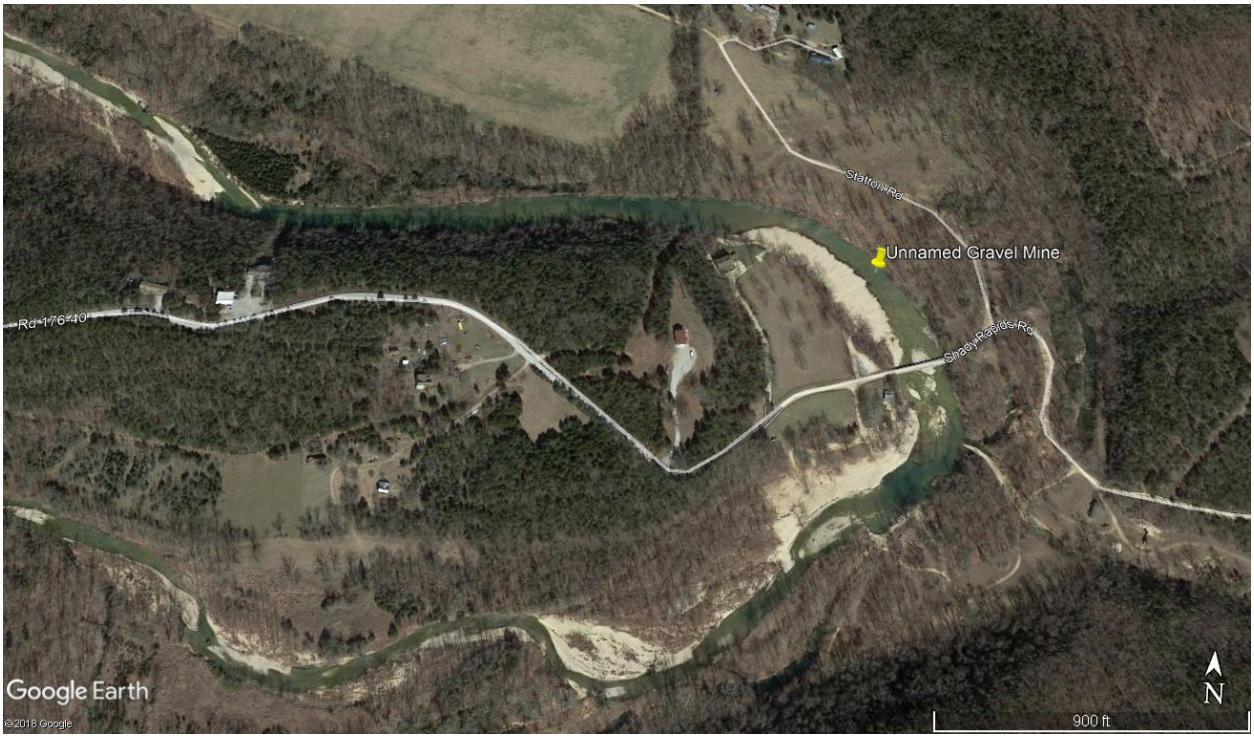
Statton Rd
Unnamed Gravel Mine
Rd 176 40
Shady Rapids Rd
Google Earth
© 2018 Google
900 ft
N

Blair St Rd
Google Earth
© 2018 Google
1000 ft
N